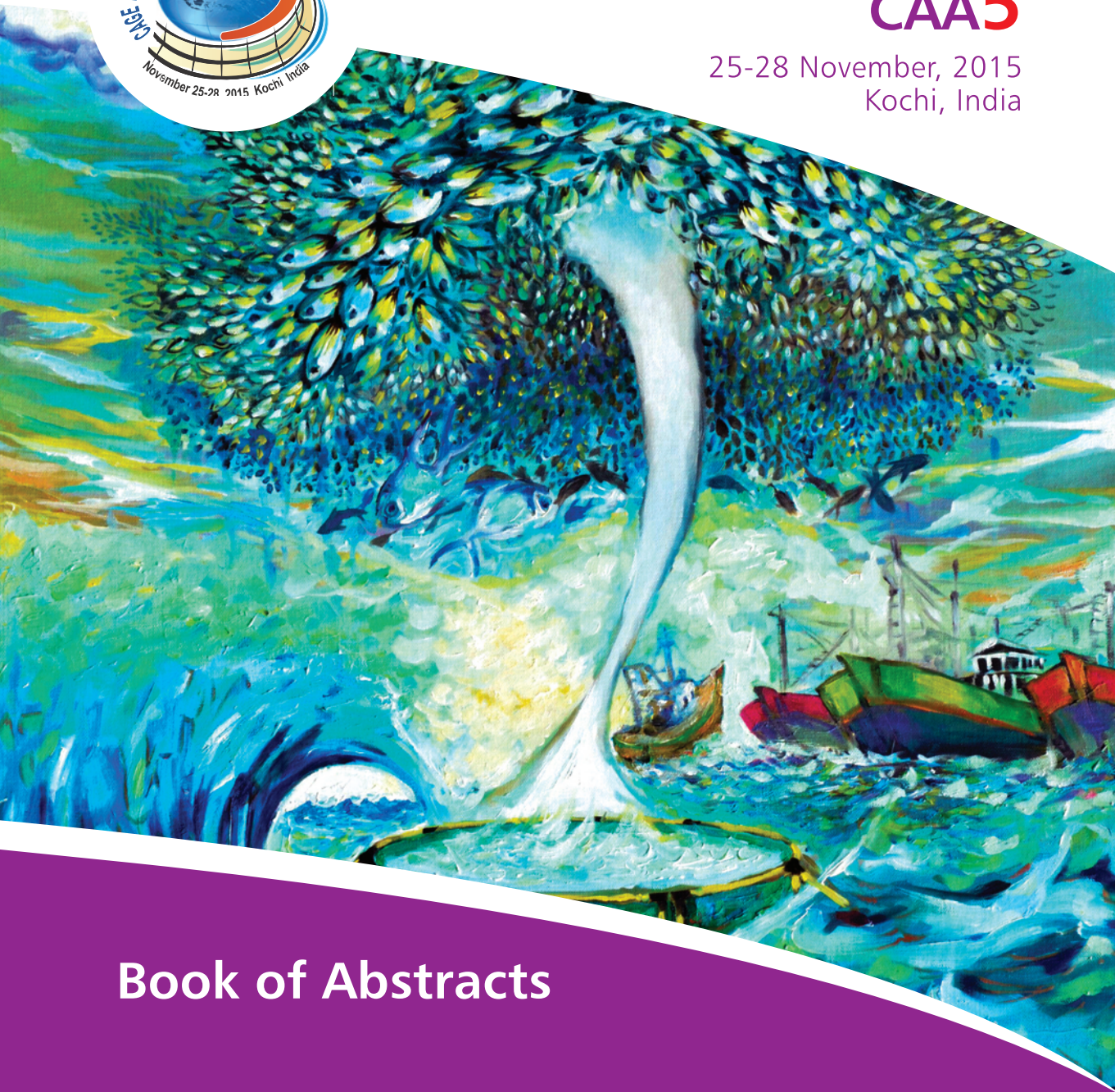




5th International Symposium on Cage Aquaculture in Asia

CAA5

25-28 November, 2015
Kochi, India



Book of Abstracts

5th International Symposium on
Cage Aquaculture in Asia

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Cage aquaculture - aiming sky high

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Foreword

Even though cage aquaculture has been widely practised in fresh and marine waters globally over the past five decades, water bodies in Asia remain underutilised. The widening gap between demand and supply for fishery products can be best met by placing a greater emphasis on cage culture. Ever since the first symposium on Cage Aquaculture in Asia held in 1999, the event provided a valuable platform for researchers and stakeholders to interact and discuss research outcomes, socio-economic implications and environmental issues associated with cage based aquaculture.

The 5th International Symposium on Cage Aquaculture in Asia (CAA5) is being organised by the Asian Fisheries Society and the ICAR-Central Marine Fisheries Research Institute (CMFRI), in association with the Asian Fisheries Society Indian Branch, from the 25th to 28th of November 2015 at Kochi, India. The event will cover an array of topics related to cage culture under the broad headings of Marine Production Systems, Inland Production Systems, Breeding and Seed Production, Nutrition and Feed, Health and Environment Management and Economics, Livelihood and Policies.

CAA5 will feature a Symposium Theme Lecture, Keynote addresses, lead talks and invited presentations from a galaxy of international experts in the field of aquaculture, as well as oral and poster presentations pertaining to recent advances and research activities in the field. We have received over 150 submissions and the best of those selected for the Symposium are summarised in this book of abstracts.

On behalf of CAA5, I thank the researchers who shared the results of their hard work with us. We also express our gratitude to the speakers who accepted our invitation to share their valuable experiences and knowledge with us. It is hoped the information collected in this publication will prove useful to policy makers, researchers and aquaculturists in promoting sustainable cage based aquaculture activities in the Asian region.

25 November 2015

A. Gopalakrishnan
(Convener, CAA5 &
Director, CMFRI, Kochi)

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Symposium Theme Lecture



Greening the Asian cage aquaculture construct

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Keywords: Cage aquaculture, Green aquaculture, Responsible aquaculture

Asia contributes to over 90% of aquaculture production of the world. During the past few decades, emergence of cage aquaculture as a promising activity in many parts of the world, including Asia, has resulted in a scenario change in aquaculture production. Over 80 marine and 20 freshwater species are grown in cages in Asia. Each country has its own approach with respect to species, seed sources, feeding, grow out, management and marketing. However, focusing on increasing production while overlooking the principles of responsible aquaculture makes most operations not green. While some countries of Asia have firm and implementable norms and guidelines for cage aquaculture, most others do not. How GREEN is the current cage aquaculture construct in the Asian region and what needs to be done for greening the approaches for cage aquaculture form the topic of the present paper.

As a strategic region providing 90% of farm grown fish to the world, Asia does not have a regional planning, monitoring and greening agenda. Do the current operations threaten the resilience of natural fishery resources, ecosystem health and stability? Are the technologies used for seed procurement, feeding, management considered as viable, resource/environment friendly and sustainable? Is there an equitable share of profits for all players? Are the approaches economically viable in the long run and inclusive? Are there dangers of introduction/escapes and spread of non-native species, genetic pollution? Are there dangers of introduction of native or alien viral, bacterial and parasitic diseases in intensive culture systems? Most of these are well known to all, but there are no implementable action plans to make the cage aquaculture green in the Asian region.

Emerging era of fish-food sector poses challenges and opportunities for Asia. Addressing the challenges of safe fish for humans, eco-labelling, traceability, certification, trade and non-trade barriers should engage our attention. With the ultimate objective of moving on to a regime of certified safe farmed fish for world markets, the Asian cage aquaculture construct must address concerns about eutrophication, other environmental impacts, indiscriminate collection of wild seed, use of low value fish for feeding farmed fish, increased use of fish meal for fish feed, threat of alien species from escapes, genetic pollution, use of chemicals and antibiotics and a host of other concerns. We must think beyond producing more fish.

If Asia is successful in collectively greening its cage aquaculture construct, it will continue to retain its primacy in the coming decades. Concerted and serious thoughts and action plans are needed.



Marine Production Systems



Automation in cage operations and new designs

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Keywords: Cages, Feeding, Norway, Salmon, Sensors

The vast majority of technical inventions and developments in cage farming have come from the salmon cage farming industry in Norway during its 40 year history. Plastic cages, steel cages, nets, moorings, monitoring systems, feed systems, feed barges, production and process control software are some just to mention the most important ones. Even though salmon farming is only 3.6% of the world's fish farming production, it is the clear technology driver and lead money maker in intensive aquaculture. Scale of economy has been a crucial success factor, and has only been made possible by fast moving innovation, automation and new designs into bigger and bigger cages for more exposed farm sites, large and efficient feeding barges, advanced video monitoring of feeding, extensive use of environmental sensors, customized heavy duty work boats and well boats, and the list goes on. The Norwegian Standard (NS9415:2009) certification of cages, nets, moorings and feed barges as well as professional site surveys have also been important to prevent fish escapes and equipment failure, thereby ensuring a predictable and sustainable salmon farming industry, economically, environmentally and socially. Other key elements that often lacks, but must be in place, include: Regulatory framework for an aquaculture industry, capital investment and operational cost financing, professional management, market and distribution channels for the fish. The presentation will give a good insight into today's salmon farming industry in Norway, and a peek into what also could be the future of cage farming in emerging markets.

Development of a viable cage farming sector for the production of marine finfish in India: the way forward

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Keywords: Finfish, Feed, Sea cage, Seed, Site

It is well understood that the catch and catch rates of many high value marine finfishes have declined in recent years and hence, cage farming is the major option to enhance production to meet the growing demand. In the recent past, marine finfish mariculture has been expanding rapidly with an average annual growth rate of 9.3%. The major groups which are farmed include salmonids, amberjacks, seabreams, seabasses, croakers, groupers, drums, flatfishes, snappers, cobia, pompano, cods, puffers and tunas. Even though sea cage farming for finfish has expanded in recent years on a global basis, India is still in its infancy in cage farmed marine fish production. A good deal of R & D efforts have been undertaken in this sector, resulting in better designs of cages developed to suit the local conditions and successful participatory sea cage farming demonstrations were also carried out at several locations viz. Vishakhapatnam, Kochi, Mangalore, Chennai, Balasore, Karwar, Mandapam, and Vizhinjam. These demonstrations have created awareness on the prospects of sea cage farming in India and many fishermen and entrepreneurs are coming forward to take up the programme. In this regard, the initiative taken by Cobia Aquaculture Fishermen Welfare Association by incurring all the expenses on their own and profitably carrying out cage farming of cobia at Mandapam is worth mentioning. A successful demonstration of cage farming of cobia integrating with seaweed carried out at Mandapam is also a positive step towards the development of Integrated Multitrophic Aquaculture (IMTA). However a lot of vital steps have to be taken to commercialize sea cage farming in India. Identifying suitable sites for cage farming on a GIS platform in the Indian Coast is of prime importance. Availability of the required seed stock supply has to be ensured. Formulation and production of suitable grow out feeds deserves urgent attention. Carrying capacity assessment of the cage farms in relation to environmental sustainability is an essential precaution. In short, the identification of suitable cages, farming sites, availability of required seeds, formulation and production of cost effective grow out feeds, economically viable farming protocols, carrying capacity assessments for sustainability, health management protocols, evolving integrated farming systems, provision of financial assistance by developmental agencies, appropriate marketing strategies and evolving sea cage farming policies are major steps forward in the development of a sea cage farming sector for marine finfish in India.

Prospects and challenges in sea cage farming in tropical Asia

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Keywords: Aquaculture, Asia, Cage farming, Production, Tropical

Aquaculture production statistics show that Asia is, by far, the leading producer in the world. However, looking into the details, it is seen that fish farming in sea cages in the tropical region contributes very little to food production compared to the large and underutilized area with optimal sea conditions available in tropical Asia. In 2013 the world produced 6,568,000 tons of fish in marine and brackishwater. About half of this was freshwater species like salmonids and tilapia. If only looking at “real” marine fish (incl. Asian seabass and milkfish) the production was 3,272,000 tons, of which Asia produced the vast majority 2,794,000 tons, which is a high volume, but more than half of this volume was produced by Japan, Republic of Korea (ROK), China and Taiwan and only 1,279,000 tons were produced in tropical Asian region. Furthermore according to the statistics, most of the tropical production took place in brackishwater *i.e.* ponds (milkfish alone contributing to 977,000 tons). Only 155,000 tons of marine fish were produced in marine environment, likely using some sea cage farming technology. Statistics may likely be under reported or possibly the farming environment criteria has not been used stringently, but the paradox is clear, when compared to Norway’s production of 1,245,000 tons of salmonids in sea cages in 2013 under more hostile climatic conditions and having a population of only 5 million people as compared to Asia’s more than 4 billion people!!

Outside the tropical Asian region it has proven possible to establish sustainable large volume farming in sea cages *e.g.* of salmonids in Europe and Americas, bass/bream in Mediterranean and carangids in China and Japan, but why is large volume production still in a continued or endless pioneering phase in tropical Asia? The presentation will elaborate on this paradox of why the tropical Asian production of marine fish is so low while seemingly possessing the best physical conditions in the tropical region to become the “seafood basket of Asia”.

Sea cage culture of spiny lobster in southeast Asia

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Keywords: Cage aquaculture, *Panulirus*, Spiny lobster

Development of spiny lobster aquaculture is of increasing interest around the world, as demand increases and capture fisheries supply decreases. There have been two primary sectors of research and development activity supporting this development; firstly, that utilizing natural settlement of lobster seed, and secondly, that developing hatchery technology. Ultimately the two sectors will merge when hatchery technology is fully commercialized and price of hatchery produced seed is equivalent to that of the natural supply, but for the time being, lobster aquaculture is 100% reliant on natural seed supply. Spiny lobster farming is well developed in Vietnam and developing in Indonesia, Philippines and Malaysia. There is strong interest throughout Asia, motivated by the success of the Vietnam industry which now generates around 1,500 tons of annual production of premium spiny lobsters, marketed to China and with a farm-gate value of \$US 150 million.

The Vietnam lobster farming industry is based on a local supply of naturally settling seed that are captured primarily at the swimming puerulus stage. Between 1.5 and 3.5 million seed are caught each year, 50 to 85% of which are *Panulirus ornatus* and the balance mostly *Panulirus homarus*. The lobsters are successfully on-grown in simple sea cages, providing a lucrative return for the village-based farmers who dominate the industry. In Vietnam there are currently around 40,000 sea cages used for lobster production. In Indonesia, a significant resource of naturally settling seed has been identified, with catch from just one location in the southeast of Lombok estimated to exceed 10 million seed per year. Grow out production however is negligible due to lack of farming skills and a preference to catch and sell the seed available. The Vietnam industry may benefit from this, as the bulk of seed exported from Indonesia are destined for Vietnam. Nevertheless, opportunity exists throughout Asia, where sea cage aquaculture is suited, using the supply of seed now being traded across the region. Sea cage grow out of tropical spiny lobsters represents one of the most lucrative aquaculture enterprises in the world, as it is founded on simple technology, minimal capital, moderate operating costs, and producing a very high value product, for which demand is well beyond supply.

Innovations in cage farming technologies along the west coast of India: A regional approach

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Keywords: Cage farming, Cost effective, Dismantlable cages, GI cages, Innovative technologies

Central Marine Fisheries Research Institute (CMFRI) initiated open sea cage culture in India. Efforts were continuously made by CMFRI, with the involvement of the fishermen community, to standardize the cage culture technology. CMFRI had initially succeeded in designing 15 m dia HDPE cages in 2007. Later, after recognizing the problems faced with net exchange as well as stability of the 15 m dia cages, a 6 m dia HDPE cage, with an additional base ring in the middle for more stability, was designed. CMFRI initiated culture of Asian seabass *Lates calcarifer* initially in these cages and achieved successful production during 2009. Developing affordable cage designs was one of the priorities of the Institute and Karwar Research Centre of CMFRI focussed on developing sustainable cage culture technologies, to help the local fishermen community in developing alternative livelihood options. Since the HDPE cages were capital intensive and fishermen could not afford such investment, a 6 m dia galvanized iron (GI) cage was designed initially which costs only ₹40,000 and involved local fishermen community for cage culture of Asian seabass, as a demonstration programme. With the success achieved from this trial, Karwar Research Centre looked forward to design different sizes of steel cages having provision for higher stocking density and production capacity. All the cages were developed using B-class 1.5" GI pipe with double welded joints. The fabricated structure was provided with single coat epoxy primer and double coat epoxy grey paint to prevent rusting. Nets of the steel cages were designed in such a way that the outer net is 60 cm above water level with no provision for predatory fishes to enter the space between the inner and outer nets. To aid floatation, fibre barrels of 200 l capacity filled with 20 lb air were used. Total weight of the cages varied from 200 to 220 kg and provided a good working platform for cage related works. The cost of 6 m dia steel cages including nets, barrels, ballast pipe, ballast weight and other accessories, put together is about ₹1,00,000 with a durability of 5 years. With successive experiments on cage farming and further innovations in cage designing, cage farming became a success along the Indian coast. The GI cage designed, developed and patented by the Karwar Research Centre changed the cage culture history of the country. This steel cage is the work horse of the cage culture industry along the Indian coast at present. Improvement in the cage design made steel cages bigger, which can be factory produced and site assembled. Cages of 8, 10 and 12 m dia were fabricated and being used in cage farming of cobia and have achieved a record growth of about 10 kg in 12 months of culture period.

Advances made by RGCA in open sea cage culture of Asian seabass *Lates calcarifer* in India

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Keywords: Asian Seabass, Export, India, Open sea cage farming, Production

Asian Seabass *Lates calcarifer*, is a protoandrous, euryhaline and stenothermic fish and therefore is suitable for both freshwater as well as seawater culture. Seabass is a sturdy fish that can tolerate crowding as well as other wide environmental changes. The fish is easy to wean to pellet diets and can grow rapidly reaching harvestable size (500 g to 1 kg) in six months to a year. The fish has high fecundity rate and hence facilitate seed production in captivity which makes it an ideal candidate for aquaculture operations. Aquaculture of Asian seabass started in 1970's in Thailand and later spread to different parts of Asia. With a global production of 75,374 tons (2013), Thailand is the major producer with an annual production of around 8000 tons since 2001.

Rajiv Gandhi Centre for Aquaculture (RGCA), the R & D wing of the Marine Products Export Development Authority (MPEDA) embarked on a project on seed production of Asian seabass in the year 2000 at Thoduvai village in Sirkali Taluk of Nagapattinam Dt., Tamil Nadu. The project established a hatchery facility for the development and dissemination of technology on seabass seed production in hatchery systems as well as a demonstration farm for the development and demonstration of technologies on seabass cage culture in land based ponds. Several demonstrations on feasibility of seabass cage farming in grow out ponds have also been carried out at the aquaculture demonstration farm of RGCA at Karaikal as well as in the ponds of farmers to popularise seabass culture. The project has also standardised and demonstrated technologies in nursery rearing of Asian seabass from fry to fingerlings in cages.

A grow out farming demonstration of Asian seabass was carried out by RGCA at its open sea cage farm in Muttom, Tamil Nadu using commercial pellet diets. Five thousand numbers of seabass fingerlings produced in RGCA hatchery having average length of 11.4 cm and average body weight (ABW) of 18.4 g were stocked in square HDPE cages with 16 mm mesh size polyester knotless netting. Fishes were maintained at a stocking density of 20 kg m⁻³, throughout the culture period. They were fed on pellet feed twice a day. The fishes attained marketable size of 580 - 600 g in 6 months period and 800 g - 1.4 kg (960 g ABW) in 10 months culture period. A total of 3.65 tons were harvested with a feed conversion ratio (FCR) of 1:1.48.

Cage culture in the northern Persian Gulf

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Keywords: Cage culture, Iran, Persian Gulf, Seabass

Cage culture is one of the fast growing aquaculture sector in the Persian Gulf. At the moment, the Iranian Fisheries Organization is promoting this fast growing industry in the northern part of the Persian Gulf, the Sea of Oman and in the Caspian Sea. Given the high salinity (from 37 to 40 psu) and temperature fluctuations (from 16°C in winter to 36°C in summer) in the Persian Gulf, very few fishes can survive and adapt to this harsh environmental conditions. To date, only European seabass (*Dicentrarchus labrax*) has been able to adapt to the environmental conditions of the Persian Gulf. Other species such as sobaity, seabream and cobia were farmed experimentally, but thus far have not been able to survive. Successful cage culture of seabass has been attempted across Kish Island near Gorzeh Village. The results show that Thai seabass is better adapted for cage culture in the northern Persian Gulf waters, when compared to Australian seabass. Efforts are being made to ensure the supply of the juveniles from local hatcheries and/or from overseas (France), to be used in southern part of Qeshm Island. Marine environmental impact assessment of fish cage culture is in its early stage, and pollutants can have adverse effects on environment in the near future if proper mitigation procedures are not followed.

An introduction to spatial planning for sustaining small scale cage culture and integrated aquaculture

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Keywords: *Aquaculture zoning, Estuaries, Small scale cage culture, Spatial planning*

Mariculture development in India has gained momentum in recent years and since the sea and estuaries are common property in India, any mariculture development activity should be well planned, taking care of ongoing activities in the water bodies. Spatial planning of maritime activities will provide a desktop decision making tool for reducing conflicts and sustaining production. In Karnataka, the technology for small scale cage culture in estuaries was successfully demonstrated for the first time in 2009, ever since there have been steady progress in small scale cage culture in terms of cage design and intensity of farming and there is a great demand from the fishermen for extending the culture activities. To streamline the aquaculture development in right direction, and to ensure higher production without any conflict of water use, the spatial planning of coastal waters has been initiated in Karnataka. Spatial planning takes into consideration, the present status and future development of the region, including fishing, tourism, industries and aquaculture.

Spatial planning experiments were carried out along the coast of Byndoor with special reference to Sumana-Byndoor River Estuary. Multi-criteria decision analysis methodology was used for the study, taking into consideration navigational path, water current, water depth, water quality, sediment characteristics and organic load on the bottom of the water body for selecting sites for mariculture. The carrying capacity studies which are being completed will provide optimum number of cages rafts/pens for crab culture that can be installed in the water body without disturbing the existing ecosystem. The maps for the present fishing area along the coast, tourism potential of the area, present fishing activity like marine fisheries, estuarine bivalve and crab fishery, use of the water body for navigational purpose, future prospects of crab fattening/crab culture in pens in mangrove area, possibilities for bottom culture of clams in sandy areas, potential seed production and seed nursery facility for finfishes and shellfishes, present areas of shrimp farming and areas which can be developed for shrimp farming are indicated. The areas of high organic load, where no culture practices can be attempted are also mapped to provide information useful for future entrepreneurs. This is the first attempt at spatial planning and aquaculture zoning from Indian waters and the maps will help in deciding the method which can be adopted to extend mariculture activities in specific water bodies with eco-friendly and human friendly concept. It also gives master plan for overall development of the area.

Preliminary study on cage culture of cobia *Rachycentron canadum* in Gulf of Mannar, Thoothukudi, Tamil Nadu

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Keywords: Cage culture, Cobia, Growth

Effective utilization of near shore waters for cobia farming in floating cages will support the fishermen as an alternative livelihood as the fishermen can earn income even during fishing holidays and non-fishing seasons. Cobia *Rachycentron canadum*, a marine finfish of high quality with white meat and growth potential can be developed as a high value, export oriented species for mariculture sector of our country. Two 6 m dia HDPE cages and three wooden cages of 4 x 4 m were moored at 1.5 km from the Tharuvaikulam sea shore. The depth of the water column was 4.3 m with sandy bottom. The cages were tied with HDPE inner net of 2.25 m depth and a braided outer net of 2.5 m depth. Cobia seeds purchased from Rajiv Gandhi Centre for Aquaculture (RGCA) were reared in concrete tanks up to 150 g size for a period of two months and 15 days and then transferred to sea cages. The fishes were stocked at the rate of 4 m⁻³. The slow sinking grouper feed (Uni President) was used which was very well consumed by cobia. The finished feed contains crude protein (CP) 43%, crude fat 10%, moisture 10%, crude fibre 1.0% and ash 15%, with feed size of 15.8-16.2 mm. Fish were fed once a day at a feeding rate of 2 - 3% body weight (BW). The food conversion ratio (FCR) was 1.9. The water quality parameters recorded during the culture period were: salinity: 33 - 38 ppt, dissolved oxygen: 6 - 9 mg l⁻¹, ammonia: 0 - 0.25 ppm, and no significant amount of nitrate or nitrite were noticeable. Production of 8 kg m⁻³ with an average weight of 4.5 kg in a period of ten months, excluding the period of rearing the seeds in the hatchery, was obtained. It was quite interesting to note that there was no disease reported throughout the culture of cobia in sea cages.

Culture of juvenile spiny lobster *Panulirus polyphagus* in open sea cages in Maharashtra

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Keywords: Cage culture, Growth, Spiny lobster, Tribal fishers

Under the Tribal Sub Plan (TSP) Scheme of the Planning Commission, Government of India two Tribal Fisher's societies each from Shrivardhan and Dahanu were identified for lobster culture in open sea cages. Four 6 m dia galvanized iron (GI) circular cages were installed for capture based culture of spiny lobsters. Juvenile lobsters (50 ± 5 g total weight) from trawl and dol net bycatch were used for stocking. Two seed cages (3 m dia) were maintained in an adjacent site at Arnala as back up for juvenile lobster holding. Each cage was stocked with 250 juveniles.

Lobsters were fed with trash fish at 10% of body weight thrice a day. After a culture period of 120 days average weight of 136 ± 8 g and 162 ± 6 g were recorded while harvesting at Shrivardhan and Dahanu respectively. Maximum survival rate of 62% was recorded from cages at Dahanu whereas survival rate of 45% was recorded from Shrivardhan. The harvested lobsters fetched price of ₹ 500 per kg at Shrivardhan whereas at Dahanu it was ₹ 800 per kg. The income generated through the sale of the produce was shared by participating tribal fishers. The technology enabled tribal fishers of Maharashtra to utilize undersized juvenile lobsters for rearing in open sea cages to marketable size and thus gain higher returns.

Growth of hatchery produced green mussel spat integrated with finfish culture in open sea cage: implications for integrated multi-trophic aquaculture (IMTA)

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Keywords: Cage culture, Multi-trophic aquaculture, *Perna viridis*, finfish culture

Integrated multi-trophic aquaculture (IMTA) is a multidimensional concept that utilizes the available unit space augmenting the production efficiency of the system. It also enables nutrient recycling among trophic levels and can be exploited by bivalves in integrated culture. The aim of the study was to evaluate the sex dependant growth of hatchery produced spat of the green mussel *Perna viridis* in suspended culture in box cages at two stocking densities and at two depths. Green mussel spat with mean dorso-ventral measurement (DVM) of 17.7 mm and mean total weight (TWT) of 0.6 g were stocked at 200 (T3) and 400 (T4) numbers per netlon screen box cage and suspended at 2 m (T1) and 3 m (T2) depths along with the open sea grouper cage moored off Visakhapatnam coast in Andhra Pradesh, India and cultured for 30 days, during February - March, 2011. The specific growth rate (SGR) in DVM, total weight and thickness (THK) were comparatively higher in females in all treatment groups, but antero-posterior measurement (APM) was only marginally higher. The growth in weight was highest at a depth of 3 m. Survival was highest at 3 m depth with a stocking density of 200 per box cage and lowest at 2 m depth with a stocking density of 200 per box cage. The difference in DVM was significant between the sexes at T2 and T4 treatments ($p < 0.05$). There was no significant difference between sexes of APM in T4; of THK in T2 and T3; of TWT in T2. They attained comparably good growth (mean DVM of 45.98 mm, total weight of 9.7 g, meat weight of 2.7 g and meat% of 28.83 in females and average DVM of 42.28 mm, total weight of 7.87 g, and meat weight of 2.36 g and meat% of 30.63) in 30 days of open sea multi-trophic culture. The females showed increase in DVM, APM, THK, total weight, meat weight and shell weight while males showed increased meat percentage. Meat percentage was highest when cultured at a density of 400 and depth of 3 m in both the sexes and lowest at density 200 and depth of 2 m for male and at density 400 and depth of 2 m. However, there was no significant difference in the growth parameters irrespective of sex with respect to stocking densities and depth, when cultured along with finfish. The suitable density was found to be 400 numbers of green mussel spat and culture depth at 3 m in a multi-trophic aquaculture system.

Advances made by RGCA in cage farming of cobia *Rachycentron canadum* in India

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Keywords: *Cage farming, Cobia, Export, India, Production*

Cobia, *Rachycentron canadum* also known as black king fish which is a highly prized fish with high value both in both domestic and international markets. The faster growth rate (attains 6 - 8 kg per year), adaptability to captive breeding and acceptance of pellet feed are the major attributes which makes cobia an excellent candidate species for aquaculture.

Rajiv Gandhi Centre for Aquaculture (RGCA), the R & D wing of the Marine Products Export Development Authority (MPEDA) initiated a pilot scale project on seed production and sea cage culture of cobia in the year 2008 at Pozhiyoor near Thiruvananthapuram, Kerala. RGCA has been successful in breeding cobia and achieved mass production of cobia fingerlings. Several sea cage rearing experiments and demonstrations carried out using hatchery produced seed in sea cages deployed at Muttom Sea, Kanyakumari, Tamil Nadu during May 2011 - July 2015 yielded encouraging results. All culture experiments were carried out exclusively using extruded pellet feeds and produced over 88 tons of cobia from its sea cage farm facility during the above period.

HDPE sea cage culture systems for Andaman Islands, India

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Keywords: *Cage systems, HDPE, Tiger grouper*

There is tremendous potential for farming of marine finfish in the seas around Andaman Islands. The island network has plenty of naturally protected areas with required depths that are suitable for installation of open sea cages for marine finfish culture. Rajiv Gandhi Centre for Aquaculture (RGCA), the Research and Development wing of the Marine Products Exports Development Authority initiated Grouper Project in Andaman Islands with the aim to set up grouper hatchery facility and to develop grouper sea cage farming. Sea cage rafts made up of different materials were tried out at the project site. Wooden cage rafts of 5 x 5 m dimension were fabricated and erected at the site, which were found to have a shorter life span and were easily prone to damages requiring frequent maintenance. These were gradually replaced with HDPE cage rafts of 3 x 3 m dimension. The cage rafts along with watchman shed were moored using grapnel, samson type and plough type anchors. The HDPE cage fabrication materials such as 250 mm double holed brackets with accessories were imported, 250 mm and 110 mm HDPE pipes were procured in India. The HDPE cage rafts were butt welded indigenously on shore and later towed to the cage location for mooring. Double layered net cages with an inner nylon knotless mesh and outer knotted net cages were used to hold the grouper broodstock and fingerlings for grow out culture. These cage structures have withstood three major cyclones; Thane, Lehar and Phalin that originated in the Bay of Bengal in the recent years without any major damages.

A suitable location measuring 400 m² of sea area was selected near Rutland Island, South Andaman (lat. 11° 29' N, long. 92° 40' E) to establish sea cage station to hold and condition grouper broodstock for the breeding programme as well as for the demonstration grow out farming of groupers in floating net cages.

Growth rate of cobia *Rachycentron canadum* in relation to cage environment in a marine cage farm off Karwar, Karnataka: a case study

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Keywords: *Cobia, Environmental health, Growth rate, Marine cage farming*

Cage culture of cobia *Rachycentron canadum* was undertaken for the first time at Karwar Research Centre (KRC) of CMFRI during 2011 in 6 m dia galvanized iron (GI) cage with initial stocking density of 4 nos. m⁻³. A record growth of 10.5 kg after 300 days of culture was achieved with 80% survival and feed conversion ratio (FCR) of 1:1.3. After this initial trial, KRC made further attempts to study the growth rate and survival of cobia and also the environmental health of cage site during the subsequent years i.e. 2012 - 13, 2013-14 and 2014 - 15. The study revealed that the growth rate of cobia was high during the summer months. Significant variation was observed in growth rate of cobia within the culture period in different experiments during the period, whereas no variation was observed between the years. Studies on environmental quality were also carried out to understand the impact of variations in the water quality on fish growth and survival. The study revealed significant variation ($p > 0.05$) in the salinity and dissolved oxygen levels of cage site at different depths and showed a positive correlation between water temperature and growth rate of cobia during the culture period ($r = 0.75$). A significant variation was observed in the ammonia levels of water at different depths near the cage site but no variation was found in their levels at the reference site. Microbial studies of water and sediment at cage and reference sites revealed no significant variation in the total bacterial loads between the sites. But the variation was high for total *Vibrio* loads of sediment from cage and reference sites within as well as between culture periods. The study for a period of three consecutive years indicated that cobia growth rate was more during summer months than in winter months.

Sea cage culture of cobia *Rachycentron canadum* through participatory mode at Mandapam, Tamil Nadu

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Keywords: *Cobia fingerlings, Growth, Sea cage farming, Self help groups*

A participatory technology demonstration of cage farming of cobia by two self help groups (SHGs) with the technical guidance of Mandapam Regional Centre (MRC) of CMFRI was initiated on 29th September 2012 in Mandapam Sea. About 2500 fingerlings produced in the hatchery of MRC were stocked in four circular galvanized iron (GI) metal cages of 7 m dia and 3.5 m depth. The fingerlings were stocked at the rate of 750 and 500 fishes each in two separate cages. The average initial length and weight of the fingerlings was 15.85 ± 0.5 cm and 24 ± 2.0 g respectively. The fishes were reared in the cages for a period of seven months. They were fed with low value fishes *ad libitum* twice a day. Water quality parameters were monitored throughout the culture period. Monthly sampling was carried out for assessing the growth and survival of the fishes grown in the cages. The cage was cleaned and maintained periodically with changing of holding nets once in every 2 months. During the grow out culture period, cobia reached 2.0 to 3.5 kg with an average weight of 2.8 kg. The feed conversion ratio (FCR) estimated was 5.9. A total of 4 tons of cobia was produced and were sold at a farm gate price of ₹250 per kg. The cost of production was ₹134 per kg and a net income of ₹4,65,976 was realised.

Identification of potential sites for sea farming along the maharashtra coast using remote sensing data

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Keywords: Remote sensing, Sea farming, Site selection

Maharashtra State of India is endowed with 720 km of coastline and 1.11 lakh sq. km of continental shelf. The marine fish landings are stagnated around 4.5 lakh tons though estimated potential is 6.3 lakhs tons. Catch per unit efforts (CPUE) are decreasing due to increase in number of fishing vessels warranting these available natural resources are to be used sensibly to harvest the maximum produce for the betterment of mankind. Mariculture will be the best option to harvest maximum produce from the available natural resources. All the available natural resources can not be brought under culture and suitable sites are needed to be identified for commercial production of marine aquatic organisms through mariculture. Identification of suitable sites for mariculture is tedious as well as time consuming task and requires huge amount of spatiotemporal data. Remote sensing is one the techniques capable of providing spatiotemporal data with a synoptic view. The present study was planned to develop the algorithms to identify the potential sea farming sites on the basis of available spatiotemporal remote sensing data.

Spatiotemporal *in situ* data of required parameters such as temperature ($^{\circ}\text{C}$), chlorophyll-a (mg m^{-3}), transparency (m), depth (m), salinity (ppt), pH and current speed (m sec^{-1}) were recorded all along the 720 km long coastline of Maharashtra covering 249 sampling stations during past four years. Spatiotemporal sea surface temperature (SST) variation patterns of the coastal area of Maharashtra were generated by converting the radiometric records of AVHRR sensor of NOAA-19 satellite. The maps with spatiotemporal variations in chlorophyll-a concentrations and suspended sediments concentrations (SSC) all along the coast of Maharashtra were generated using OCM sensor data of Oceansat-II satellite. The maps of turbidity were generated from same sensor of Oceansat-II. Depth surface of coastal area was developed by giving input of sea truth depth record collected during the sampling as well as depth points recorded from isobathymetric lines on the admiralty charts of National Oceanographic Office. Descriptive score sheets for all the parameter of interest were generated. Spatiotemporal variation maps of all parameters were classified as per the developed descriptive scales. Classified maps of all the parameters were merged together to generate common map. Areas suitable for culture were identified on the basis of threshold limits from common map. As output of the study, a model is developed to identify the potential sites for culture of fish using remote sensing data and the maps with suitable areas for open sea cage culture for all the coastal districts of Maharashtra were developed.

Growth performance of pompano *Trachinotus blochii* in two farming environments

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Keywords: *Cobia, Cage farming, Growth, Pond farming*

Growth of pompano *Trachinotus blochii* was studied in two farming systems viz. cage farming and pond farming. Hatchery bred juvenile pompano were stocked in cages moored in Kochi backwaters and in brackishwater ponds in the nearby area. The water intake to the pond was from the same place where the cages were moored so that the water quality remained almost the same in both places. Floating cages of size 4 x 4 x 3 m were used. HDPE net bags having various mesh openings were used at various stages of growth. Net changes were done in every 10 days during initial period and later once in 25 days. The pond selected for farming was scientifically prepared by eradicating all unwanted weed and predatory fishes and by adding lime and fertilisers to have a healthy bloom of phytoplankton. Feeding in both systems was done using artificial pellet feeds. Commercial floating pellet feeds containing protein of >45% was used. The water quality at both sites was recorded. Observations were made on growth, specific growth rate (SGR) and survival.

During 165 days of culture in cages, the average weight gain was calculated as 91 g and length increment was 14.82 cm. The average daily growth rate was calculated as 0.55 g. In pond farming environment, the fishes grew to an average size of 248 g in 150 days and the length increment was 18.6 cm in the same period. The average daily growth rate in ponds was 1.6 g. The survival rate was above 90% in pond farming as there was only very few numbers of mortality during the initial days of stocking, against survival of 60% in cage. The fishes were very active and healthy in both farming systems.

Growth in cages observed in the present study is low compared to growth in ponds. The growth obtained from ponds was comparable to the data reported elsewhere. An average growth of 220 g and 22 cm in 165 days was reported from pond farming in Andhra Pradesh in coastal ponds. The water quality conditions and associated net clogging in the brackishwater environment may be a reason for reduced growth in cages. It was observed that fouling on cages was very high in the brackishwater environment. Introduction of grazers like pearlspot may reduce clogging by algae, which may in turn benefit the water flow inside the cages.

Pompano (*Trachinotus blochii*) farming: an intermediate crop in coastal hyper-saline shrimp ponds in Gujarat

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Keywords: Grow out, Intercrop, Nursery, Hyper-saline ponds, Pompano farming

The snubnose pompano *Trachinotus blochii* is considered as one of the most enviable food fish for mariculture, due to its tolerance capabilities during culture and fair market price. Pompano is a tropical fish generally found in waters with a temperature range of 26 to 32°C and salinities ranging from 30 to 37 ppt. Feeding habit of the species is selective grazing, dominantly feeds on bivalves, crabs, shrimp, and various fish species. Culture experiments were conducted on nursery rearing in the hyper-saline coastal ponds during winter period (inter crop period) using seawater. The seeds of pompano were acclimatised at 34 ± 2 ppt during nursery period, after which seeds were stocked in nursery ponds. One thousand seeds with an average stocking size of 1.0 ± 0.2 g were stocked for a culture period of 120 days. In the present experiment, the survival and growth rate observed were 88% and 0.28 g day^{-1} , respectively. Grow out farming was undertaken in low saline shrimp ponds with an average stocking size of 35 ± 4 g for 160 days of culture. The fishes were fed with formulated feeds having 48% protein and 8% fat at the rate 10% of body weight. The average growth rate achieved during grow out farming was 1.04 g day^{-1} . Average size at harvest was 200 ± 10 g and it fetched fair market price of around ₹300-350 per kg. Water quality parameters were monitored at fortnightly intervals and no health issues were observed during the culture period. Pompano farming in shrimp farms as intercrop will give add-on returns to the shrimp farmers as it possess excellent demand in both domestic and export markets.

Comparative evaluation of growth performance in Asian seabass *Lates calcarifer* in seawater and freshwater

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Keywords: Cage culture, Freshwater, Growth, *Lates calcarifer*

A 60 days experiment was conducted to evaluate the growth of Asian seabass *Lates calcarifer* juveniles in different conditions from freshwater (0 ppt) to seawater with varying salinity range (25 ± 5 ppt) at Karwar Research Centre of Central Marine Fisheries Research Institute (CMFRI). Asian seabass juveniles with average length and weight of 3.8 ± 0.79 cm and 6.4 ± 0.95 g respectively were stocked in circular FRP tanks (500 l) filled with adequately aerated freshwater and seawater, each in triplicates (30 juveniles per replicate). The fishes were fed with commercially available pelleted feed and periodical sampling for growth parameters was done at weekly intervals. Weight gain, specific growth rate (SGR), feed efficiency ratio (FER), average daily gain (ADG), weight gain %, protein efficiency ratio (PER) and feed conversion ratio (FCR) were calculated at the end of the experimental trial. Results indicated that growth in terms of weight gain was higher in freshwater (10.54 ± 0.36 g) and low saline waters as compared to seawater (10.14 ± 0.21 g), which was statistically non-significant. The present study clearly revealed the potential of *L. calcarifer* as a new candidate species for diversification of freshwater aquaculture in reservoirs which at present holds great promise for increasing inland fish production in India.

Demonstration of high value palinurid lobster culture in small scale cage holdings in Raigad District of Maharashtra

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Keywords: Cage, farming, Growth, *Panulirus polyphagus*, Small scale, Survival

Efforts were taken to evaluate capture based aquaculture (CBA) of high value mud spiny lobster *Panulirus polyphagus* under National Agriculture Innovation Project (NAIP) Component-III, Sub project "Strategies to enhance adaptive capacity to climate change in vulnerable regions" (World Bank-GEF) in Raigad District of Maharashtra. A total of seven - small galvanized iron (GI) floating sea cages (3 m inner dia) were deployed during 2013 - 14 at Aadgaon, Bharadkhol, Bagmandala, Turumbadi, Dighi, Borli Mandala and Sasawane in Raigad District. Out of these sites, only at Bharadkhol successful growout of *P. Polyphagus* was achieved. The wild caught juveniles (70 ± 20 g IBW) of *P. polyphagus* were stocked in 3 m dia cage during November to February 2014 and reared for a period of 114 days. Lobsters were fed daily in the evening with locally available fishes like *Sardinella longiceps*, *Sardinella* spp. and other trash fishes @ 10-15% of body weight. The caged lobster grew at 1.04 g day^{-1} which resulted in 228 g of percentage weight gain. The percentage survival was found to be 58 which produced 23 kg of total biomass. The recorded hydrological parameters were optimum for the growth and survival of lobster. The harvested lobsters fetched ₹1400 per kg in the local market that generated gross revenue of ₹32,200. The encouraging results of small scale cage holdings ensured alternate livelihood to the fishers.

Capture based aquaculture of lobsters in open sea cages: sustainable use of natural resources

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Keywords: Capture based aquaculture, *Panulirus polyphagus*, Rock lobster, Specific growth

Rock lobster *Panulirus polyphagus* was selected as a candidate species for their high price with good market demand both in domestic as well as foreign market. The juveniles of the species are abundantly available in nature and show good growth rate under captive condition. The species is hardy in nature and shows good survival during transportation and culture. The species is considered ideal for capture based aquaculture (CBA) as the young ones (<100 g) are usually treated as bycatch and does not command good market price. Fattening of these young ones to exportable size (>200 g) increases the price and thus makes the culture practice profitable. The present study indicated that *P. polyphagus* is a suitable lobster species for open sea mariculture in net cages from the wild collected seed resources. Rock lobster *P. polyphagus* were reared at four different stocking sizes and stocking densities in open sea cages to evaluate the growth performance. Lobsters in various size groups i.e. 60-80 g, 81-100 g, 101-120 g and 121-140 g were stocked at similar stocking densities with triplicates. The growth trial lasted for 90 days. The stocking densities experimented were 5 m⁻², 7 m⁻², 9 m⁻² and 11 m⁻² in triplicates. The experiments lasted for 120 days. The highest final body length and weight was recorded with stocking size group of 80-120 g or higher. The weight gain percentage and specific growth rates showed that the stocking densities 7 m⁻² and 9 m⁻² were appropriate for obtaining higher growth performance in sea cages. Therefore, preferably lobster seeds of 80-100 g size need to be selected and stocked at 9 m⁻² to maximize yield. The study confirmed that density-dependent mortality is also prevalent in lobster cage culture as that of tank culture, indicating the importance of choosing appropriate stocking densities and initial stocking sizes for optimal survival and viable economic farming practices.

Grow out culture of lobsters in wooden net cages at Thoothukudi, Tamil Nadu

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Keywords: *Growth, Live lobsters, Wooden net cages*

Two suitable sites for sea cage culture were selected in Manapad Bay at Thoothukudi coast and a trial on lobster culture was conducted in low cost fixed wooden net cages. The dimensions of wooden net cage was 3 x 3 x 1.5 m, fabricated with 30 mm mesh size for both inner and outer net. The bottom net is fixed 0.5 m above ground level. Total depth in the high tide and low tide was 1.8 m and 1.2 m respectively. Undersized soft-shelled live lobsters (in the weight range 60 - 80 g) were collected from different landing centers along the Thoothukudi coast. Stocking density of the lobsters ranged from 1100 to 1250 nos. per cage (95 - 110 nos. m⁻³). Calcareous stones and plastic crates were placed at the bottom of the net cage panel as substrates. Lobsters were fed once in a day during morning hours (10.00 hrs) with cuttlefish waste and low value fishes at 5 - 8% body weight. Water quality parameters recorded during the culture period were: salinity 31- 34 ppt, temperature 28 - 32°C and pH 7.9 - 8.2. Partial harvest of lobsters was done in every 25 - 30 days interval and fortnightly sampling of the lobsters was carried out to assess the growth in terms of length and weight. During our observation period, 18 to 20% of the stocked lobsters grew to 100 g and above within a month. Moulded shells, uneaten feed, dead animals and debris were removed daily. The seed lobsters were purchased at ₹240 to 300 per kg and the market price of lobsters (100 g and above) varied from ₹1200 to 1800 per kg.

Suitability of the bigeye trevally *Caranx sexfasciatus* for cage aquaculture in coastal waters

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Keywords: *Cage aquaculture, Carangid fish, Coastal waters*

Cage farming in India is carried out in marine, brackishwater as well as freshwater ecosystems. Seabass/barramundi and redsnappers are the important and popular cultured finfishes in brackishwaters of Karnataka. Most of the barramundi production is based on hatchery reared seeds while redsnapper production relies on capture based aquaculture (CBA). Seed transportation from available locations in the east coast is the major bottleneck for the expansion of the culture along the coastal waters of Karnataka. In the present study, the suitability of bigeye trevally was evaluated as an alternate species for brackishwater cage aquaculture in the region.

Bigeye trevally seeds are available in plenty in the estuaries of Karnataka (September - January) forming a part of bycatch in the small shore seines operated in the region. Though they are landed alive, due to the small size they do not have market value and hence are discarded on the beach. For the present study, such small sized live seeds (50 to 85 g) were collected and immediately shifted and stocked in two cages of 4×2×2 m size made of Netlon lined with nylon net. Stocking was done @ 300 nos. per cage during December - January 2014. The fishes were fed with low value fishes @ 6-8% of their body weight. After a culture period of about 150-180 days, the big eye trevally reached an average size of 300 - 450 g. An average of 125 to 150 kg of fish were harvested from two cages with the survival 80-90% at the end of six months. Apart from higher growth rate, the species attract good demand with market price of ₹350 - 400 per kg. This is the first instance of bigeye trevally seeds collected from the wild were grown in cages. The availability of seeds in the wild, faster growth rate and the good market price makes bigeye trevally a suitable species to be considered for mariculture in cages in inshore areas of Karnataka.

Indian halibut *Psettodes erumei*: a new resource for grow out culture in India

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Keywords: Cage culture, Candidate species, Indian Halibut

Psettodes erumei or the Indian Halibut is reported in India both on the east coast from False Point to Ganjam, Andaman Sea, Odisha, Madras, Kakinada, Gopalpur; Parangipetta to the west coast of Neendakara and along Karnataka waters. Landings of Indian halibut declined from 6.7% in 1985 to about 0.005% of the total flatfish landed during 2014. Except for occasional large sized samples of *Psettodes erumei*, landed in fishing harbours, the species is not landed regularly in the fishery. The scenario indicates alarming decrease in the population of the fish in Indian waters. Several reasons including climate change could affect the distribution of a particular species and hence their susceptibility to particular fishing fleets, becoming more or less "catchable" as a result.

Two pleuronectids are included in the IUCN listing, the Atlantic halibut, *Hippoglossus hippoglossus* as Endangered, and the yellowtail flounder, *Pleuronectes ferrugineus* as Vulnerable. Efforts were already initiated to breed the flounders and halibuts which have shown decline in temperate waters. Looking at the decline in population of the Indian halibut, *Psettodes erumei* calls for stringent conservation measures as well as conservation mariculture. In contrast to the temperate species, no major effort has been initiated in India on the development of breeding technologies, nor cryopreservation or gene banking of this species. Very little information has been generated on the breeding biology of *Psettodes erumei*, *Pseudorhombus javanicus* and *Pseudorhombus arsius*, the three large sized flatfish which can serve as food fish. It is suggested that conservation mariculture and capture based aquaculture in cages can be initiated for development of broodstock and further culture of the species to augment the fishery of Indian halibuts keeping an eye on its resource potential.

Enhancement of spiny lobster production by cage culture: a new horizon for traditional lobster fishery in India

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Keywords: *Capture based sea farming, Conservation, Spiny lobster fishery management*

Spiny lobsters are highly valuable, nutritionally rich seafood delicacy having great demand in Asia, Europe and America. Due to the increasing demand and high prices from domestic and international markets, lobster fishing has been intensified over the years in India. Lobster fishing in India is an open access fishery which is mostly carried out by traditional fishermen. The lobster fishery in coastal area is comprised by two categories viz. spiny lobsters or rock lobsters inhabiting in rocky area at 1-20 m depth and slipper or sand lobsters inhabiting at 20-50 m depth zone on sandy bottom. The annual lobster landings in India have been declining from a peak of 4,075 tons in 1985 to the present annual average of 1,546 tons. Unlike other marine fishery resources in the wild, lobster stock is very much limited because of their specific geographical distribution, limited genetic and species diversity accompanied by prolonged larval life stages. All these factors contribute to high compactness in the fishery with low complexity, favouring immense potential to implement fishery management options to achieve sustained production and conservation of the fishery. In the present study, the economic and biological loss as a result of exploitation of juveniles and spawning population of the lobsters was assessed and analysed. The concept of augmenting lobster resources on a long term basis using cage culture with various management options for conservation and sustainable management of lobster resources was also analysed. Special emphasis has been given to 'capture-based sea farming' of berried lobsters in small submerged marine cages as a community based activity by providing incentives to the fishermen. Implementation of this program would ensure sufficient larval recruitment in the sea and thereby increased production, resulting in the improvement of socio-economic conditions of traditional fishermen. In view of organized clandestine poaching prevalent among the fishermen, necessary guidelines on acceptable 'social regulations' for fishery management along with other lobster conservation programs are also suggested.

Low cost capture based multispecies culture system for coastal waters off Goa

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Keywords: *Etroplus suratensis*, Low cost, *Lutjanus argentimaculatus*, Multispecies, *Perna viridis*

Goa state encompasses huge potential for coastal fishery enhancement with unutilised coastal water bodies. There is ample scope for coastal aquaculture to improve coastal fish production in Goa. However, there exists a deficiency of adaptive culture systems for coastal aquaculture in the state. To address this issue, Central Coastal Agricultural Research Institute (ICAR-CCARI) carried out a trail on low cost multispecies capture based culture system in coastal waters off Goa. In the continuous stocking and harvesting system, finfishes like redsnapper *Lutjanus argentimaculatus* and pearlspot *Etroplus suratensis* were cultured in combination with green mussel *Perna viridis* for a period of eight months. Finfish seeds obtained from the bycatch during the normal fishing operations (average size: pearlspot - 50 mm, redsnapper - 200 mm) were separately stocked in three nylon hapas (pearlspot - two hapas, redsnapper - one hapa; hapa dimension - 2 x 1.5 x 2 m) positioned using bamboo poles. Mussel seeds (average size - 32 mm) collected from the wild were stocked (1 kg per bag) in fifteen pre-stitched cotton mosquito net bags centred with nylon rope (length -1 m, dia - 14 mm). The bags were hung from the bamboo poles used for fixing the hapa. In finfishes, redsnapper was fed with chopped discards (ghost crabs, small weed fishes and molluscs according to body weight) and pearlspot utilised the periphyton developed on the split bamboo pieces kept inside the hapa. Mussels utilised the plankton available in the water through filter feeding. The total cost of the culture system (3 hapas) and operations was ₹0.14 lakh and total returns from the system was ₹0.54 lakh. The net profit from the culture was ₹0.39 lakh. This system can function as a source of alternate livelihood for the fisherfolk youth in Goa.

Cage as a tool to validate growth parameters of oil sardine and Indian mackerel

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Keywords: Cage culture, Growth parameters, Indian mackerel, Oil sardine

Experimental cage culture of oil sardine *Sardinella longiceps* and Indian mackerel, *Rastrelliger kanagurta* was conducted to revalidate their growth parameters off Visakhapatnam from December 2013 to September, 2014. Two hundred numbers each of oil sardine (average length of 32 ± 3 mm) and Indian mackerel (average length of 159 ± 2 mm) were collected in ring seines from wild and stocked in 6 m dia HDPE cage moored at 10 m depth. No extraneous feeding was done during the experimental period. At every fortnight, randomly 15 nos. of each species were sampled for observing increments in length and weight. After 8 months of rearing in cage, oil sardine reached an average length of 158 ± 3 mm and Indian mackerel attained 242 ± 2 mm. The growth rate of oil sardine and mackerel obtained from cage were compared with the earlier published growth estimates using length frequency data. Present experiment revealed that the growth rate of both the species is better in cage when compared to length frequency based growth rate estimates in the wild populations.

Cage culture of the Pacific white shrimp *Litopenaeus vannamei* at high stocking density in a creek in Andhra Pradesh

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Keywords: Cage culture, Creek water, High stocking density, Pond culture

Litopenaeus vannamei is one of the most important penaeid shrimp species farmed worldwide. Cage culture of this species in sea and other low saline water bodies is now being considered as an alternative approach for aquaculture worldwide. In this study, feasibility of culturing the species in cages at high stocking density in creek water was evaluated and compared with the pond reared shrimps. Two square shaped galvanised iron (GI) cages of 6 x 6 m size were used for this study. Cages were installed with the help of air filled barrels for floatation and anchors (iron) and palm tree for mooring. For both the cages, nylon nets of different mesh sizes were used to hold the shrimps in nursery and grow out phases. Similarly, shrimps were also cultured in the pond to evaluate the differences in the growth between cage and pond rearing methods. In pond culture experiment, shrimps were stocked in 2 different ponds of 1 acre water spread area. The experimental cages and ponds were stocked with shrimp post-larvae (PL 20) at 660 per m³ and 45 per m², respectively. During the culture, shrimps were fed with commercial feed four times a day. Periodic sampling was carried out to monitor the health and feeding status of the shrimps throughout the 60 days of culture period. The survival and final body weight of the shrimps were found to be 75% and 12.9 g for cage and 76% and 13.1 g for pond reared shrimp. The differences between body weight and survival of the shrimp reared in cage and pond did not show any significant differences. Findings of the study showed the possibility of Pacific white shrimp culture in cages with less expenditure, when compared to the culture in pond. Cage culture of the species in open creek water showed potential and scope for landless and small scale aqua farmers to take up shrimp culture. However, susceptibility to diseases and the issues related to culture of the exotic species in open waters need to be considered.

Site selection for open sea cage culture using spatial analytics

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Keywords: Cage culture, GIS, Remote sensing, Site selection

India possesses vast coastal water resources which can be ideally utilized for cage culture activities. Though, plenty of locations are available in coastal waters, the cage mariculture activities are not suitable at all available locations. It is essential to identify feasible mariculture sites for cage culture, for undertaking successful cage culture activities. The site selection primarily depends on the physio-chemical conditions which determine whether the species can thrive in an environment followed by weather, shelter, depth, substrate and other parameters. With advent of satellite remote sensing and the Geographic Information System (GIS) platform; we are now in a position to delineate spatially the best suited sites for cage mariculture. The marine GIS have the added dimension of depth alongside the latitude and longitude as compared to terrestrial GIS. Though cage mariculture in India is in initial phase, the geo-spatial delineation of potential cage aquaculture sites will be very useful for successful cage mariculture in the country. A few validations achieved for such site selection using above tools in Mandapam and Veraval region are illustrated.

Mathematical modelling of sea cage dynamics

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Keywords: Drag, Hydrodynamics, Indian Ocean, Ocean currents, Sea farming

Geographical location of Indian subcontinent provides excellent opportunity for the expansion of sea cage farming from experimental to industrial level. However, the inherent upheaval of tropical Indian Ocean bespeaks a sturdy design for the success of open sea cage farming. The selection of the components of cage and associated mooring system requires careful scoping of their capacity to withstand prevalent ocean waves and currents. The present study proposes a numerical model representing the dynamic forces acting upon open sea cage in Indian waters. The model is based on lumped mass method. It can be simulated to obtain the required breaking strength of cage components, under various oceanographic conditions. The model output forms vital information while selecting the design and construct of cage, mooring system and also the suitable farming site.

Design and development of an effective low cost floating seed cage suitable for nursery rearing of Asian seabass *Lates calcarifer*

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Keywords: *Lates calcarifer*, Nursery rearing, Seed cage

Traditional fish culture can be improved by rearing fishes at high density in cages, by adopting different management measures. Floating cages for broodstock development and grow out culture for various species have already been established. Asian seabass seeds having average mean total length of 2 cm are available in plenty during monsoon near Subarnarekha Estuary at Balasore, Odisha. These are either sold at minimal prices or are stocked in ponds for nursery rearing with resultant low survival rates due to improper management. In this context, an attempt was made using low cost and durable HDPE floating cages for nursery rearing of Asian seabass *Lates calcarifer* near Subarnarekha Estuary (Bay of Bengal), in Balasore, Odisha (21° 33' 35" N; 87° 20' 2" E) at 5 - 8 m depth. Four cages were installed for providing suitable environment as well as natural availability of plankton. Each experimental cage was constructed of two HDPE base frames (90 mm pipe), the inner frame of 2 m dia and the outer frame with 3 m dia. The two frames were joined by 4 nos. of HDPE base pipes (200 mm). The frames were provided with 4 vertical supports (90 mm HDPE) and a hand rail (90 mm HDPE) was provided at top for easy maintenance. All the pipes were heat joined hydraulically using HDPE of 110 mm. The inner and outer frames were filled with polyurethane foam for additional floating support. Four oil barrels were attached to the cage for providing additional buoyancy during stocking and net changing. The overall cost per cage was around ₹31,500 excluding the mooring materials, which vary according to location. Two sapphire nets (2 mm mesh) of 2 m dia and 2 m depth (Garware) were used both as inner seed net and as outer predator net. Polypropylene bird net of 40 mm mesh size was used to prevent birds preying on the fish. The water quality parameters recorded during the rearing period were: pH 7.2 - 8.1, salinity 16 - 23 ppt, temperature 23 - 28°C and dissolved oxygen 5.8 - 7.9 mg l⁻¹. Caged fishes were fed with *Acetes* and wheat flour mix. A survival of 14 - 32% was recorded after four months of nursery rearing. The results of the present trial indicated the advantages of low cost durable floating cage as a tool for nursery rearing of Asian seabass in estuary, over the traditional nursery rearing in ponds. The present study offers scope for further refinement in cage design with use of alternate materials for reducing the cost without affecting the stability of the cage.

IPS

Inland Production Systems



Enclosure aquaculture in inland waters of India

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Keywords: *Freshwater aquaculture, Fish production, Environmental concerns*

Fish, being accessible and affordable for the poor, plays a prominent role in meeting the protein requirement in the developing world. It is predicted that fish consumption in the third world will increase by 57%, from 62.7 million tons in 1997 to 98.6 million tons in 2020. Projected requirement of fish in India by 2021 is estimated at 12.0 million tons. In order to achieve this target, the sector needs to record a growth rate of about 6% per annum, a tough goal, but achievable. Some key inputs for fish production such as water and land are becoming scarcer on account of conflicting demands from other sectors of development. Further, fish production from natural water bodies are subject to the negative impacts of overfishing and habitat degradation. All these, coupled with the other environmental concerns including emerging issues posed by climate change, constitute the major constraints in meeting the future demand for fish. During the last five decades, contribution of marine fish in the total production has decreased from 71% in 1950s to 39% during 2010 - 11 with a corresponding increase in inland fish production. This shift in catch structure in favour of the inland segment is attributable to the growth of inland aquaculture, as opposed to the sole dependence of capture fisheries in the marine counterpart. In view of the dwindling production from natural waters, both inland and marine, any substantial increase in production has to come either from inland aquaculture or mariculture.

Inland aquaculture presently contributes 4.2 million tons of fish annually (FAO, 2014). At present, the three Indian major carps viz. catla, rohu and mrigal constitute 87% of freshwater aquaculture production. Several variants of carp culture such as wastewater recycled culture, integrated agriculture aquaculture (IAA) and short term culture are also available. However, freshwater aquaculture in India by and large still centres around pond based systems. Considering the ever increasing demand for land and water bodies owing to diverse and often conflicting demands on them, there are limitations for growth in pond based aquaculture. In this context, culture of fish in enclosures such as cages and pens installed in open water bodies offer scope for increasing production obviating the need for more land based fish farms. Considering India's rich and varied open water resources like reservoirs, lakes and floodplain wetlands, enormous scope exists to increase production through enclosure aquaculture. However, these activities have not yet reached commercial proportions capable of making any impact on the production figures. The scope and current status of enclosure aquaculture has been discussed in the paper.

Responsible cage fish farming: integrated approaches

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Keywords: Cage culture, High density aquaculture, Pearlspace, Responsible aquaculture

Intensive fish farming in open water cages and enclosures is a relatively new development in India, with profound economic, social and environmental consequences. The first experiment on cage fish farming in Kerala was started in 1998 in Vembanad Lake by the Regional Agricultural Research Station (RARS). Farming of fish was undertaken in small closed type hard cages of size 2 - 4 m², constructed of plastic netting suspended from floating wooden platforms and anchored in deeper portions of the open estuary in inland locations and tidal channels in lake Vembanad. The endemic cichlid *Etilapia suratensis*, popularly known as pearlspace, was demonstrated to be a supreme species. The success of this first venture was received with mixed responses. The success of artificial breeding and development of hatchery protocols for seed production of pearlspace boosted interest in cage culture. Later, a participatory entrepreneurship development program was initiated at RARS, Kumarakom and a cage farm was established and operated exclusively by a women self help group, viz. Vembanad Swayam Sahaya Sanghom, Kumarakom under the aegis and support RARS. To overcome the dependence on expensive factory made feeds, a feed unit was established close to the cage farm as an integrated activity and a branded fish feed for pearlspace was marketed. Later, several organizations and the Government came up with cage farming programs. However, lack of definite Government policy for lease of public waters for fish farming deterred entrepreneurs from commercial ventures.

Open water cage farming is often cited as a means to relieve pressure on wild fish stocks that are exploited beyond capacity. However, carnivorous fishes, that form bulk of the farmed fish worldwide, are fed on wild caught fish, either directly or as fish meal in fish feed, increasing the pressure on ocean fisheries. Expansion of cage aquaculture with a higher degree of feed input and waste output also raises concerns about the effects of the wastes on the quality of receiving water systems. Hence, restrictions are essential not only on sites used for cage farming but also unscrupulous stocking and feeding practices. There should be strict adherence to 'cage to open water' ratio in order to avoid pollution of inland freshwaters. The possibility of enclosing rivers and lakes by powerful interests is in conflict to the interest of the 'ecosystem people'. The situation demands a need to weave together ecological and technological productivity to a more equitable and sustainable process. Open water cage farming regulated as a responsible cluster activity established and operated by the local people is the right approach.

Cage aquaculture in inland open waters of India: retrospect and prospect

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Cage culture was attempted in India for the first time in 1970, with air-breathing fishes in swamps, which are marked by low dissolved oxygen (DO) in water, major carps in running water in rivers Yamuna and Ganga at Allahabad and common carp, catla, silver carp, rohu, snakeheads and tilapia in still water bodies in Karnataka. In the seventies, cage culture in wetlands of Assam was attempted by researchers of the Central Inland Fisheries Research Institute (CIFRI) which got a strong foot hold in the nineties. A few trials on cage aquaculture were later attempted and some isolated work on cage culture for raising fingerlings as well as table fish in reservoirs viz. Powai (Maharashtra), Govindsagar (Himachal Pradesh), Halali (Madhya Pradesh), Tandula (Chattishgarh) and Dimbe (Maharashtra) have been done. Recently, cage aquaculture experiments were conducted in Walvan Reservoir, Maharashtra with mahseers *Tor putitora* and *T. khudree*, for rearing fry to fingerlings. At present, a large number of cages have been installed in different reservoirs in a number of states viz. Jharkhand - 1200, Chhattisgarh - 120, Madhya Pradesh - 144, Mizoram - 72, Rajasthan - 48, Maharashtra - 168, Uttar Pradesh - 96, Karnataka - 48, Telangana - 48, Himachal Pradesh - 48, Gujarat - 100, Odisha - 144, TamilNadu - 64 and Nagaland - 24 nos. One remarkable cage farming enterprise in India is the Chandil Cage Culture in Jharkhand. A number of entrepreneurs like Indepesca Overseas Pvt. Ltd. (IOPL), Das & Kumars and Neelkamal including a number of feed producers are involved with cage culture projects across India with very modest results. Fish cage culture taken up by the Fisheries wing of Kerala University, with the support of Rashtriya Krishi Vikas Yojana (RKVY) and the Department of Fisheries, Govt. of Kerala is worth mentioning. In Nalbari District of Assam, cage culture in 1 m³ bamboo cages installed in small rivulets with moderate flow for raising grow out fishes of *Anabas testudineus* and *Labeo rohita* (Jayanti Rohu) was tried. The technology was perfected for raising stocking materials and subsequently for table fish production which was immediately taken up under Mission Mode Project (NMPS) by the Department of Animal Husbandry Dairying & Fisheries (DAHD&F), Govt. of India with the spread of cage culture activities in 12 states of India. The technology has gained its strong footing with the cultivation of good candidate species across India which has modest bearing on livelihood of rural India in future.

Cage aquaculture in reservoirs: the Indian experience with special reference to Madhya Pradesh

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Keywords: Cage culture, Madhya Pradesh, *Pangasius*, Reservoir fishery

Madhya Pradesh is a land-locked state with an average productive fisheries area of about 0.4 million ha in the form of reservoirs and ponds. Fisheries activity is a co-operative based venture in the state and the fishing rights of ponds/reservoirs up to 1,000 ha AWSA have been given to tri-layer Panchayat Raj System. Presently the per hectare fish production of village ponds is around 1375 kg and irrigation ponds is about 85 kg. Government of Madhya Pradesh has given the fishing rights of major reservoirs (above 1000 ha AWSA) to the Madhya Pradesh Fisheries Federation Co-operative Ltd. (Federation), which is scientifically managing and looking after the welfare of fishermen working in its reservoirs.

The diurnal as well as seasonal variation of atmospheric temperature in the state varies from 2°C during winter to 45°C during summer. This condition poses limitations to culture fisheries and the reservoirs are used mainly for capture fishery. Usually the fish seeds of Indian major carps are stocked in the reservoirs every year. To augment fish yield, the Federation has started cage culture in reservoirs with the support from Govt. of India under the scheme of National Mission for Protein Supplement (NMPS). Four cage units (each unit having 48 nos.) have been installed in 3 reservoirs (Indirasagar, Gandhisagar and Halali). The species opted for culture was *Pangasianodon hypophthalmus*, as recommended by Project Implementation Committee of NMPS. The results of the first crop are very encouraging (about 5 tons of fish per cage which is about 2000 tons ha⁻¹). Due to the state's geographical conditions, it takes about 18 months time to harvest the fish from the cages. The value of *Pangasius* in the market is low, as a result its production is not economically viable. In this context it is required either to decrease the production cost by use of local/low cost fish feed or choose any other species of fish which may give high sale price. Availability of good quality seed is also an issue. Initial investment in cages is also high. Therefore, low cost cage should be searched for. It has also been observed that the results of *Pangasius* culture in small ponds gives better results as compared to cage culture. With this new venture a huge opportunity of getting high production of fish from the limited controlled area within the reservoirs can be obtained. In Madhya Pradesh if we use about 10% of the area under reservoirs, the fish yield can be augmented many fold thereby addressing the malnutrition problem of the people at large. The economic condition of the fishers can be improved to a great extent by using modern technologies and new scientific interventions.

Present status, potential and prospects of cage culture for fisheries enhancement in Indian Reservoirs

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Indian reservoirs with water spread of 3.15 million ha and estimated yield potential of 100 - 150, 200 and 500 kg ha year⁻¹ for large, medium and small reservoirs respectively offer enormous scope of enhancing the productivity through culture based fisheries. Cage culture in inland open waters is being looked upon as an opportunity to utilize existing reservoirs with great production potential to enhance fish production and is being posed as an answer to increasing demand for animal protein in the country. Various reports indicate that more than 15 states have already adopted cage culture technology in inland waters with varying levels of success. It has been estimated that fish production in the range of 15 - 70 kg m⁻³ year⁻¹, can be achieved through cage culture, depending on the fish species and intensity of management. During such intensification of fish production through cage culture, the carrying capacity needs to be determined in order to maintain the ecological integrity and sustainability. Ensuring stocking of quality fish seed, eco-friendly, low cost and nutritionally balanced feed and disease management would be the key mantras for expansion of cage farming in reservoirs. The recent success of cage farming in Jharkhand and Chattisgarh has set a benchmark and proved the potential of cage culture in the country. Fish species diversification based on regional preference would ensure popularization and profitability of enclosure culture practices. Development of seed production technology and suitable strains of preferred native species will facilitate adoption of cage culture across the country and will decrease the risk of bio-invasion by exotic species. Cluster approach needs to be undertaken in developing seed and feed production infrastructure, creating facilities/hubs for broodbanks, expanding market links, and improving processing and value addition technology for smooth access and profitability. Ascertaining suitable policy framework for governance and institutional arrangement would be vital in realizing the mission of blue revolution from open access, multi-stake water resources. Encouraging the site specific public-private partnership (PPP) mode of management will give an impetus to fisheries development, besides ensuring the equitable distribution of benefits. It may be envisaged that the realization of production potential of reservoirs can reduce the demand-supply gap through horizontal expansion of technologies, introduction of semi intensive enclosure culture system, development of trained manpower and improvement in governance through policy support. In the present study, an attempt was made to review and synthesize the current status, potential, opportunities and future research and management needs with regard to cage culture and to develop state-wise strategies for enhancement of fisheries in the Indian reservoirs in a sustainable way.

Cage culture of catfish *Pangasianodon hypophthalmus* in Krishnarajasagar Reservoir, Karnataka: a case study

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Keywords: Cage aquaculture, Nutrient load, *Pangasius*, Reservoirs

The sutchi catfish *Pangasianodon hypophthalmus* is a fast growing omnivorous fish. Commercial culture of this fish has been popular in land-based pond aquaculture in some states of India such as Andhra Pradesh and Telengana. Commercial cage culture in general is still in the nascent stage in India. Public agencies in several states such as Jharkhand and Karnataka are conducting large scale trials for production of table size sutchi catfish in cages in reservoir environment, with the intention to popularize this system of culture. States such as Telangana and Andhra Pradesh are in the process of installation of cages in many reservoirs for the culture of this fish. The growth, yield, economics and marketing of this fish in cages are yet to be documented in detail in different agro-climatic zones of India. Information on the impact of cage culture on environment is also scanty from Indian reservoirs.

Sutchi catfish were grown in 24 cages of 6 x 4 x 4 m (96 m³), floated in Krishnarajasagar Reservoir (Area: 13000 ha; lat. 12° 25' 30" N; long. 76° 34' 30" E), constructed across river Cauvery in Karnataka State. Catfish were reared from fry (mean length 25 mm) to fingerlings (125 mm) for 80 days in ponds (survival 60%) and then stocked at an average density of 52 fish per m³. Floating extruded pellet feed of 6.0 mm dia having 30% protein was fed twice a day at 5% body weight in the beginning (till the fish reached 150 g body weight) and slowly reduced to 2% (when fish reached 500 g body weight). Mean fish weight of 1.0 kg was attained in eight months of growth period. The average feed conversion ratio (FCR) recorded was 1:2.1 and the mean survival was 90%. The mean production per cage was 2116 kg and the total production was 56.79 tons with an average yield of 24.60 kg m⁻³. The estimated nutrient loading due to cage culture operations was 3.3 tons of nitrogen and 226 kg of phosphorous. The economics of farming and problems of marketing are also discussed.

Effect of stocking density on growth of *Tor khudree* fingerlings in floating cages at Kerwa Reservoir, Madhya Pradesh

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Keywords: Cage, Food conversion, Growth, Stocking density, Survival, *Tor khudree*

A study was conducted from December 2012 to April 2013 at Kerwa Reservoir near Bhopal, Madhya Pradesh, India to evaluate the effects of stocking density on growth, survival rate and food conversion ratio (FCR) of *Tor khudree*. Seeds (fingerlings) were reared at three different stocking densities (100, 200 and 300 fingerlings m^{-3} , i.e. T1, T2 and T3 respectively) in floating cages of dimension 4 x 4 x 3 m with knotless HDPE net of 4 mm mesh size. The average size of fingerlings stocked was 36.52 mm and weight 0.71 g. There were four replications for each treatment. Growth data viz. length and weight of individual fish in each cage were recorded on monthly basis. Supplementary feed (crude protein 26-35%) was given to all the twelve cages @ 8-10% of the body weight daily in three equal parts. Fish attained mean final weight of 6.3 ± 0.97 , 9.18 ± 2.42 and 4.52 ± 1.41 g in treatments T1, T2 and T3 respectively. The FCR was found to be 1.71, 1.12 and 2.59 respectively. Specific growth rate (SGR) recorded was 1.807, 2.121 and 1.544% body weight per day respectively, in the treatments T1, T2, and T3. Mean survival rates were 72.59, 77.99 and 64.11% respectively. Water quality parameters revealed acceptable ranges for aquaculture. It could be concluded that at a stocking density of 200 fingerlings m^{-3} (T2), growth rate and survival rate were the highest. The present study is a modest attempt to demonstrate optimum rearing density of *T. khudree* in enclosure system to promote mahseer culture with better growth, production and survival as well as effort towards its conservation.

Prospects of cage culture of the exotic carp *Barbonymus gonionotus* in a freshwater composite fish farming system at Birbhum District, West Bengal

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Keywords: *Barbonymus gonionotus*, Cage culture, Composite fish farming, West Bengal.

The exotic carp *Barbonymus gonionotus*, commonly known as Java barb (length: 1.44 ± 0.08 cm and weight: 0.81 ± 0.12 g), was cultured in cages (3 m^3) at six different stocking densities; designated as C1 (40 m^{-2}), C2 (50 m^{-2}), C3 (60 m^{-2}), C4 (70 m^{-2}), C5 (80 m^{-2}) and C6 (90 m^{-2}); in freshwater pond along with the existing composite fish farming system for 105 days. The maximum mean length (16.15 ± 0.18 cm) was recorded in C1 and the maximum mean weight (28.79 ± 0.30 g) was recorded in C4. There was no significant variation in the body weight increment ($p > 0.05$) at different stocking densities. Length-weight relationship showed positive and significant ($p < 0.001$) correlation between the different stocking densities. The condition factor (K) of the fish was maximum (29.40 ± 0.31) in the initial days of culture and became minimum (0.71 ± 0.31) after 105 days of culture. The condition factor significantly differed due to change in stocking density of fish. The maximum survival percentage (96%) was observed at the lower stocking densities (C1-C4) and it was the minimum in the higher stocking densities (C5-C6). Specific growth rate (% of length day^{-1} and % of weight day^{-1}) and average growth rate (%) decreased with increase in culture period. Gross production increased with the increase in stocking density and culture periods. It was maximum ($2.53 \pm 0.11 \text{ kg m}^{-2}$) at the highest stocking density (C6) and minimum ($1.16 \pm 0.08 \text{ kg m}^{-2}$) at the lowest stocking density (C1). Like production, net income was the maximum at the highest stocking density (C6) and gradually decreased with the decrease in stocking density. From the preliminary study it was concluded that cage culture is a novel option for enhancing the net income from farming. In addition, the limitation of the exotic fish culture along with the native fish may be solved by implementing cage farming simultaneously with the existing three species (*Catla catla*, *Labeo rohita* and *Cirrhinus mrigala*) in composite fish farming systems in West Bengal. Fast growing and high valued carnivorous fish are available in West Bengal, but their commercial culture along with planktivorous or herbivorous carps in the existing composite fish farming system is not possible. This problem may be solved by the introduction of cage culture in the prevailing composite fish farming system. Further studies are required on the optimization of cage size, stocking density, supplementary feeding and species specific guidelines for the promotion of cage culture in the country.

Cage culture of groupers in protected bays and creeks of the Andamans

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Keywords: Cages, Cannibalism, Grouper, Serranidae

Andaman and Nicobar islands situated in the Bay of Bengal have numerous bays, creeks, lagoons and islets with varying depths and different substrates which are suitable for cage culture. This study was initiated with an objective of designing cages suitable for protected bays and evaluating the feasibility of grouper culture in Andaman. Four cages of 5 x 4 x 3 m each, were fabricated using wooden frames and made afloat using 24 empty barrels. Two anchors of 50 kg each were used to anchor the cages at Minnie Bay, Port Blair. The net webbing, procured from Central Institute of Freshwater Aquaculture (CIFA), Bhubaneswar, was fitted to the mainframe and tied to the vertical supports. Groupers belonging to the genus *Cephalopholis* (*C. argus*, *C. miniata* and *C. boenak*) and genus, *Epinephelus* (*E. merra*, *E. fasciatus* and *E. longispinis*) were caught from North Bay and Chunnapatta offshore areas, for the culture. In the initial study, 210 fishes of 162.1 ± 26.95 mm length and 62.11 ± 32.18 g weight were stocked in two cages. The water quality parameters were monitored and found that dissolved oxygen (4.0 - 5.0 ppm), salinity (30 - 34 ppt), pH (7.8 - 8.1) and alkalinity (120 - 135 ppm) were within the acceptable limits for fish culture. They were fed everyday with low value fishes like *Sardinella* sp. at 5% of body weight. The net webbings of the cages were scrubbed at fortnightly intervals to maintain water flow. The growth was recorded after 4 months and an increase of 67% in weight was observed with 90% survival. In the creek area, high turbidity and intense fouling were the major issues which necessitated frequent cleaning of the net webbing and the frames. In another experiment, the cages were subsequently shifted further away from the shore where the depth below the cage during the lowest low tide was 4 m. About 150 fishes belong to the same species were collected and stocked in these cages. The average initial length and weight of the fishes were 201.7 ± 27.57 mm and 90.06 ± 41.40 g respectively. Fishes were fed with chicken offal and trash fish @ 5% of body weight. The fishes recorded a growth of 34.04% in three months with 98% survival. The culture continued for a period of six months and the fishes reached 268.43 ± 33.56 mm in length and 161.36 ± 52.64 g in weight, registering a growth of 79.17% with 96.81% survival. These successive culture experiments suggested that the fishes can be successfully cultured in cages in the protected bays and creeks in Andaman and the cannibalism can be checked by proper feeding.

Cage culture as a new avocation for women empowerment: a case study

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Keywords: Cage culture, Pearlspace, Snapper, Tilapia, Women empowerment

Cage culture in backwaters has been developed to an advanced and user friendly technology that has opened the door of opportunity for women to easily get involved in fish culture along with other backyard operations like poultry rearing and goat rearing. Galvanized iron (GI) cages of 6 x 6 m size were used in the open backwaters of Vembanad Lake at Poothotta in Ernakulam, Kerala. The location is a meeting place of 3 Districts, Ernakulam, Alappuzha and Kottayam, where lot of backwater area suitable for fish culture is available. The cage site had a depth of 4 m with good water exchange. Farming was done in a Public-Private Partnership (PPP) mode with a group of 3 educated women from local fish farmer's families. The cages were installed and moored in open waters under their supervision and other operational works such as nursery rearing of fingerlings, feeding, cleaning and grow out culture were done by the ladies. The cages were stocked with 500 numbers of locally collected pearlspace seeds (*Etroplus suratensis*) in April 2014. One thousand five hundred numbers of hatchery produced seeds of GIFT tilapia (*Oreochromis niloticus*) were procured from Matsyafed hatchery, Veliyamgodu and 150 numbers of red snapper seeds (*Lutjanus argentimaculatus*) collected from Triprayar were also subsequently stocked. The fishes were fed thrice a day with Godrej floating feed/cooked rice heat at a feeding rate of 10% body weight initially and at 7% for the last 3 months. Growth as well as the water quality parameters were monitored on a monthly basis and were in the range: temperature, 28 to 30°C, salinity 6 to 12 ppt, pH 7.8 to 7.96 and dissolved O₂ 5 to 6.26 mg l⁻¹, which indicated that the area is good for fish culture. The main attraction of the culture was the fast and good growth of pearlspace. *Etroplus* seeds grown to a size of 250 to 350 g and 16±3 cm in 4 - 6 months with a survival rate of 85% were partially harvested and sold. The tilapia attained a size of 750±65 g and 23±5 cm with in a period of 8 months and survival was about 88%. Red snappers reached 1 to 1.4 kg within 8 months. The harvested fishes were sold in the local market at a price of ₹200 kg⁻¹ for tilapia, ₹500 kg⁻¹ for pearlspace and ₹400 kg⁻¹ for red snappers.

The cage culture studies conducted revealed that women can do many activities, including nursery rearing of seeds and operational works in cage culture activities in backyard water bodies. This was a boost to rural women who are already engaged in fishing as well as to the new younger generation. Involvement of women in aquaculture proved beneficial for their socio-economic empowerment, improved income and provided an alternate livelihood option which ultimately resulted in an improved status of the women, their family and finally the society.

Engineering components in cage farming for inland open waters of India

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Keywords: *Cage aquaculture, Economic viability, Engineering, Structural integrity*

Design and engineering of cages is a major component for cage aquaculture and it is essential to select ideal construction materials, proper design, suitable mooring and good management practices (GMP) in bringing out commercial cage aquaculture which is quite simple, economically viable and socially acceptable. The system components can be technically simple but as a whole they are complex structures. From an economic perspective, the cage volume needs to be large and the mooring system must also be optimized considering both economic and structural integrity criteria. To achieve these long term goals, engineering method specific to inland open water cage culture has been developed and perfected by the Central Inland Fisheries Research Institute (CIFRI), Barrackpore.

Circular shape cages are better in terms of utilization of space but have more cost involvement per unit volume and is not suitable for freshwater sector. However, square cages are convenient to operate and easy to manoeuvre in inland open waters. The cost per cubic meter of cage volume is reduced as the size increases, but manoeuvring is difficult. Moreover larger units have the advantage of having fewer cages with the same total farm volume, saving on the material used and on the cost of management and maintenance. The water exchange inside the cage is inversely proportional to the volume of the net and depends on the speed of the current and the distance between the opposite walls. Thus, small cages make it possible to increase the stocking density considerably because of more flushing providing good ecological condition inside cages. On the other hand, small volume cages often induce loss of feed, and hence the feed conversion ratio is adversely affected. Engineering components of a cage are the most important factor besides seeds and feeds which ultimately determine the cost effectiveness of the system with stability of cage, life span and manoeuvring. Thus, it is important to develop an eco-friendly and economically viable cage, taking into cognizance all the engineering aspects involved in cage aquaculture.

Cage culture for rearing fish fingerlings in reservoirs

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Keywords: Cage culture, Carps, Growth, Reservoir

Though cage culture technology is used for high value fish production worldwide, it is still in initial stage of development in India. There is enormous potential for cage farming in Indian reservoirs. The reservoir production depends on the stocking of bigger size seed (100-150 mm) for which *in-situ* rearing of seed is essential. The Central Institute of Fisheries Education (CIFE), Mumbai has conducted multiple location trials on cage aquaculture in the reservoirs and lakes with the sole objective of raising fingerlings in the reservoirs *i.e.* Walvan Lake in Lonavala, Maharashtra, Powai Lake in Mumbai, Halali Reservoir in Madhya Pradesh, Gobind Sagar in Himachal Pradesh and Dimbhe Reservoir in Pune, Maharashtra. In these experiments, fry of 35 mm length were stocked @ 50 to 200 fry m⁻³ and feeding was done with formulated feed @ 3-5% of body weight twice a day. In the present study, two species of mahseer, *Tor putitora* and *Tor khudree* were stocked in cages at Walvan Lake Lonavala. These species were cultured from fry to fingerling and fingerlings to advanced fingerlings attained growth up to 223.85 mm (206.45 g) and 288.06 mm (285.16 g) respectively. In Powai Lake, *Labeo rohita* grew from 65.62 mm (3.24 g) to 152.11 mm (54.72 g) with survival of 50.72%. Whereas, *Cyprinus carpio* grew from 24.45 mm (0.293 g) to 105.66 mm (31.34 g). In Halali Reservoir, average growth of *Catla catla* in 8 cages was up to 105.75 mm (18.20 g) whereas, *Labeo rohita* in 12 cages grew up to 101.68 mm (14.43 g). In Gobind Sagar Reservoir production of catla, rohu and common carp was 264.01, 156.97, 167.05 and 261.54 kg respectively. The analysis of water quality parameters of all the four study sites indicated Powai Lake to be highly productive due to its very rich nutrient status, whereas, Walvan Reservoir the least productive among all these four aquatic bodies. The present study shows that cage culture is a viable proposition and a potential option for reservoir fisheries development programmes. It has also proved to be a useful technology for seed rearing in open water bodies as a fisheries enhancement programme.

Effect of artificial substrates on the growth of *Macrobrachium rosenbergii* in floating net cages

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Keywords: Artificial substrates, Floating net cages, *Macrobrachium rosenbergii*, Powai Lake

Cage culture is a low impact farming practice with high returns and least carbon emission activity. Cage aquaculture is a viable alternative to traditional techniques of rearing, due to lower cost and practicability. Artificial substrates can serve as a refuge for newly molted shrimp which are vulnerable to cannibalism. It can also provide additional surface area on which shrimps graze and this additional food resource can supplement exogenous feed. The present study was conducted at Powai Lake, Mumbai, Maharashtra to investigate the effect of artificial substrates on the growth of *Macrobrachium rosenbergii* in cages. Juveniles of *M. rosenbergii* with an average weight and length of 2.15 ± 0.01 g and 51.67 ± 0.09 mm were stocked @50 prawns m^{-2} in the cages. There were three treatments and one control, with three replicates for each treatment. In control, there was no artificial substrate, whereas, in T1 one unit, in T2 two units and in T3 three units of artificial substrates were placed. The study was conducted for a period of 120 days. At the end of the experiment, final weight was 23.37, 16.27 and 3.14% higher in treatments T2, T1 and T3 respectively as compared with control. Present study indicated that prawns in presence of artificial substrates grow 14% faster than without substrates and production rate in substrate treatment was 10% higher than that of control. The study concludes that growth of *M. rosenbergii* is enhanced in presence of artificial substrates in cages.

Scope of enhancing reservoir fisheries productivity in Uttar Pradesh through cage culture

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Keywords: *Cage culture, Reservoir, Uttar Pradesh*

Uttar Pradesh is a populous state in the country and is endowed with vast inland open waters in the form of reservoirs, lakes and floodplain wetlands. These waters are well suited for enhancement of culture based fisheries. The state has about 75 small, 27 medium and 5 large reservoirs covering water spread area of 1.57 lakh ha at FSL which can be potentially used for the fish production. The exploitation level of these waters is much below the potential due to traditional methods of fishing and non-adoption of methods for improving production. The current average fish yield of the reservoirs of Uttar Pradesh is relatively poor to the tune of about 15 kg ha⁻¹ y⁻¹ only. The overall untapped potential for the Indian reservoirs worked out to be 280 kg ha⁻¹, which is more than nine times the current fish yield. Nevertheless, the reservoirs are recognised as sleeping giants for fisheries development and constitute a most valuable but highly underutilized fishery resource. Fish yield enhancement in these reservoirs is possible by bringing the reservoirs under scientific fisheries management practices through culture based fisheries interventions. Enhancement options include stocking species of commercial value and habitat enhancements. Fingerling rearing in cages is also a promising area for the development of reservoir fisheries. Cages can be used for rearing of Indian major carp fry up to advanced fingerling stage for enhancing the reservoir productivity. Experimental cage culture in this regard as conducted by Central Inland Fisheries Research Institute in Pahuj Reservoir of Jhansi provides encouraging results. There is also great scope for rearing of ornamental fish in cages installed in reservoirs. To harness this potential it is needed to ensure effective and efficient extension system; policy to encourage entry of entrepreneurs; mainstreaming aquaculture in the existing farming practices for multiple use of water; human resource development and promotion of fish as health food. Recognizing aquaculture activity at par with agriculture, is a stepping stone by Government of Uttar Pradesh in this regard. Such enhancements will directly benefit poor traditional fisher communities, especially in the surroundings of the reservoir.

Survival and rearing of hilsa *Tenualosa ilisha* in floating cages at Ukai Reservoir, Gujarat

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Keywords: Cage, Reservoir, *Tenualosa ilisha*

Research and development efforts in the area of design and development of floating cages by the Central Marine Fisheries Research Institute (CMFRI) has resulted in confirming the stability of HDPE floating cages for broodstock development and rearing of candidate species for mariculture. Different versions of cages were designed and culture demonstrations of economically important species were performed at different locations in India. In similar lines, efforts were made to design cages suitable for rearing of hilsa *Tenualosa ilisha* at Ukai Reservoir, Gujarat. Two different types of cages were installed, rectangular (7.5 x 5 x 4 m) and circular (6 m dia and 4 m depth). The cages were made of HDPE pipes with hydraulic heat jointing. The circular cage was provided with eight vertical and eight diagonal supports of 90 mm HDPE pipe whereas the rectangular cages were provided with 10 vertical and 10 diagonal supports. The outer and inner base frames for both the cages were of 90 mm HDPE pipes and were provided with hand rail at the top. Eight floating barrels filled with polyurethane foam were fixed to the cage for buoyancy. Considering the volume of water during summer and monsoon, the cages were installed at 15 m depth using single point mooring system. Mooring was with 80 grade 13 mm alloy steel long linked chain with a revolving swivel (5 ton capacity) anchored at the bottom with 10 concrete blocks each weighing 200 kg. Nets with inner mesh of 8 and 12 mm for nursery and grow out and outer mesh of 25 mm for predator protection were attached to the cage. The water quality parameters recorded were: pH (8.3 - 8.5), salinity (0 g l⁻¹), temperature (25 - 30°C), water current (0.01-0.05 m sec⁻¹), dissolved oxygen (4.6 - 5.8 ppm), nitrite (0.01 - 0.08 ppm) and total ammonia (0 - 0.32 ppm). Circular cage was used for nursery rearing and was stocked with 600 nos. of hilsa juveniles in the size range of 50 - 70 mm (63±2 mm). Mortality of 50% was observed within 24 h of stocking and mortality reached 70% on the 5th day. Mortality rate was reduced thereafter. Two rectangular cages were used for grow out culture and were stocked with 740 hilsa fingerlings ranging in size of 130 - 150 mm (142±4 mm). Mortality of 40% was observed within 24 h of stocking and mortality reached 75% on 5th day. Thereafter, reduction in mortality was noticed and survival of fingerlings was observed to be better.

Density dependent growth, survival and lactate dehydrogenase activity of golden mahseer fry reared in floating cages

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Keywords: *Floating cages, Golden mahseer, Growth, Stocking density, Stress*

In the present investigation, two experiments were carried out to study the density dependent growth, survival and lactate dehydrogenase (LDH) activity to optimize the stocking density of golden mahseer fry in floating cages in Bhimtal Lake, Uttarakhand. In experiment 1, fry of golden mahseer (average weight 0.061 ± 0.012 g and length 1.83 ± 0.23 cm) were stocked at densities of 60, 70, 80 and 90 fish m^{-3} following completely randomized design with duplicates. After 10 months of rearing, growth and survival were studied and found that the weight gain of yearlings in 60, 70, 80 and 90 nos. m^{-3} density groups were 10.1 ± 0.31 , 9.84 ± 0.42 , 9.68 ± 0.27 and 9.81 ± 0.33 g respectively. The survival percentages were 95.7, 96.1, 95.3 and 95.5 in their respective groups of 60, 70, 80 and 90 nos. m^{-3} . The growth performance and survival showed no significant difference in different stocking density groups and therefore a second experiment (experiment 2) was conducted to explore the maximum carrying potential. For this, fry of golden mahseer (average weight 0.191 ± 0.014 g and length 2.75 ± 0.34 cm) were stocked at densities of 100, 150, 200 and 250 fish m^{-3} and reared for 10 months. The final weight was 9.12 ± 0.31 , 9.95 ± 0.61 , 8.27 ± 0.52 and 7.87 ± 0.36 g at the stocking densities 100, 150, 200 and 250 m^{-3} respectively. The survival percentage was 89.4, 85.5, 79.5 and 71.6 in the respective stocking density groups. Lowest weight gain and specific growth rate (SGR) was noticed in higher density group of 250 m^{-3} . There existed a negative correlation between stocking density and growth rate. Similarly, a negative correlation was observed between survival and stocking density. Lactate dehydrogenase (LDH) activity in liver and muscle were significantly affected by stocking densities and activities were higher at higher stocking densities suggesting density dependent stress in the fishes. Based on the study, the optimum stocking density for *in situ* seed rearing of golden mahseer in floating cages may be recommended as 150 m^{-3} . Results of this study will be of use in sustainable *in situ* rearing of golden mahseer fry in cages as a step forward for its stock enhancement and rehabilitation in Himalayan lakes. At the same time, the study manifests the potential utilization of existing open coldwater resources of uplands where land availability and nursery pond construction are major constraints.

Cage culture of milk fish *Chanos chanos* in brackishwater pond at Kochi, Kerala

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Keywords: Brackish water, cage, *Chanos chanos*, Kerala, Milk fish

The milk fish *Chanos chanos* is a marine inhabitant commercially cultured in brackishwater ponds, seawater as well as in hyper-saline lagoons and can tolerate salinities of 0 to 158 ppt. Milk fish is known to be farmed in ponds and pens in Indonesia, Taiwan, Thailand and Philippines. However, in India, so far it is known to be farmed only in ponds and pens. In the present study, milk fish were farmed in brackishwater cages at Kochi, Kerala, India. The wild collected milkfish fry (3 - 4 cm) were nursery reared in hapa net inside the cage for a period of 60 days and then stocked inside the grow out cage at a density of 50 fingerlings m⁻³. A 4 x 4 m cage positioned diagonally within the sluice pit of a traditional shrimp pond allowed water exchange to all four sides of the cage. The fish were fed with commercial extruded floating feed containing 34.0% crude protein and 4% fat from 35 to 500 g weight. A feed enclosure kept at one foot level inside the grow out net kept the floating feed within the enclosure, without being lost in water flow. The milk fish were fed three times daily at a satiation feeding time of 20 min throughout the culture period. At the end of the farming a total biomass of 500 kg or 10 kg m⁻³ with an average fish body weight of 400 g, feed-conversion ratio (FCR) of 1:2.0 and survival rate of 50% at 240 days of culture were recorded. The growth was better in cage than in the neighboring ponds, and may be attributed to the better feeding and other management practices in cage. Milk fish is best suited for culture in the tropics because of its fast growth, efficient use of natural food, propensity to consume a variety of supplemental feeds, resistance to diseases and handling and tolerance to a wide range of environmental conditions (Lim *et al.*, 2002). Though the fish is hyperactive, the activity was found to be reduced in cages. Using pellets improved the feeding efficiency due to the physical characteristics such as better stability which prevents them from dissolving and losing nutrients in the water. The farm gate price obtained was ₹200 per kg, with a total revenue of ₹1,00,000. The feed cost was ₹35 per kg and the cage and nets were re-used after the previous crop. The farmer got a net income of ₹50,000, which was reasonably good for low production traditional brackishwater ponds in Kochi, Kerala.

Cage culture of seabass *Lates calcarifer* in brackishwater fish ponds at Kakinada, Andhra Pradesh

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Keywords: *Lates calcarifer*, Brackishwater pond, Cage culture

Experimental investigations on the cage culture of seabass was carried out in well prepared identical rectangular grow out ponds in brackishwater fish farms, Kakinada. Fishes were divided into three groups and maintained in cages installed in the pond. Fishes in T1 group were fed with small fishes, T2 with mysis and T3 with small fishes along with mysis and for each treatment triplicates were maintained. Pelleted feed was given @ 10% of body weight, and live feed @ 10% of body weight twice a day to all the treatment cages. Water quality parameters and growth rate were recorded at fortnightly intervals. The water quality parameters recorded in cages were within the optimum range: salinity - 11 to 20‰ (mean 16.5‰), temperature - 25 to 31°C (mean 26.5°C), dissolved oxygen - 6-8.5 mg l⁻¹ (mean 6.8 mg l⁻¹). Survival rate of fishes in T1 group was highest (90%), followed by T2 (75%) and T1 (70%) groups. Fishes in control group recorded least survival rate (40%). The experiments revealed that fishes in group T3 fed on mysis and small fishes recorded significant growth and survival. Hence, it is recommended to feed mysis and small fishes at least during early stages of seabass culture in pond conditions.

Asian seabass *Lates calcarifer* as the most prospective candidate species for cage culture in brackishwater in Kerala

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Keywords: Asian seabass, Brackishwater, Cage, Kerala

Participatory mode of cage culture was undertaken in Cochin backwaters at different localities during 2008 - 15 for the culture of Asian seabass *Lates calcarifer*. The results indicated that the fish is an excellent candidate species for cage culture in brackishwater with good growth, survival, disease resistance, market demand and price. *L. calcarifer* fry weighing 3.5 ± 1.5 g were procured from Rajiv Gandhi Centre for Aquaculture (RGCA) hatchery at Tamil Nadu and nursery reared in hapa installed in traditional ponds for a period of 45 days, till they attained 30 - 40 g size, prior to stocking in cages. In some instances, nursery reared seed weighing about 30 g were procured and directly stocked in the cages. Indigenously fabricated square cages of galvanized iron, measuring 4 x 4 m with outer and inner frame and hand rail were used for farming. Sealed 200 l styrofoam drums were used as floats on each cage to keep the frame in floatation. The net volume ranged from 50 - 60 cubic meters. The grow out period in cage ranged from six months to one year. On harvest, the fish were of 600 to 950 g depending on the grow out period. From post-hatchery fry to harvest size, the survival was 50 - 55%; while for the nursery reared and stocked seed, survival rate ranged from 80 to 90%. The stocking density varied from 10 to 40 fish per cubic meter. The production varied from 500 kg to 2 tons depending on stocking density and duration of culture period. The farm gate price ranged from ₹250 per kg in 2008 to ₹600 per kg in 2015. The feed conversion ratio was about 1:3, on feeding with trash/low value fish. However, the feed cost averaged ₹50 per kg and only 30% of the revenue was used towards feed cost. From the series of observations of cage farming operations, it is concluded that rearing seabass in cages is an attractive endeavor that can provide handsome returns and the species is a good candidate for cage culture in brackishwater in Kerala.

Trimming of cheliped legs reduces cannibalism and increases survival in green mudcrab *Scylla serrata* reared in cage system

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Keywords: Cheliped legs, Crab cage culture, Green mud crab

Mudcrabs or mangrove crabs of genus *Scylla* are widely distributed in coastal waters, lagoons, brackishwater lakes, estuaries and intertidal swampy or mangrove areas along the coastal lines of tropical and subtropical countries. Mudcrabs have high commercial importance by virtue of their delicacy, export demand and high market price in seafood export market. The green mudcrab (*Scylla serrata*) culture is rapidly gaining importance in India due to hatchery seed availability and proven mudcrab culture technology. However, cannibalism is one of the major bottleneck which affect the low survival rate of mudcrabs in farming system. Chelipeds play a major role in growth performance of mudcrabs and loss of entire chelipeds in crabs can affect feeding behaviours and growth rate. To evaluate the effect of trimming of propodus of cheliped on cannibalism in green mud crabs, cage culture of mudcrabs with and without trimmed chelipeds was conducted in open and compartment floating cages in 2 x 2 factorial design in triplicates. A total of 72 green mudcrabs (118 ± 17 g) were stocked in 12 cages ($0.75 \times 0.5 \times 0.3$ m) @ 6 nos. per cage. The mudcrabs were fed with molluscan meat and trash fish at 5-10% body weight. After 60 days of culture, it was revealed that trimming in the cheliped's propodus significantly ($p < 0.05$) increased survival percentage of crabs reared in both open cages ($88.88 \pm 19.25\%$) and compartment cages ($94.33 \pm 9.81\%$) compared to crabs without trimmed cheliped legs in open cages ($44.44 \pm 19.24\%$) and compartment cages ($72.2 \pm 19.23\%$). It was also noticed that trimming of cheliped legs results in significant increase ($p < 0.01$) in percentage of crabs (88.87 ± 9.64 and $72.22 \pm 34.69\%$) with intact cheliped legs compared to crabs without trimmed chelipeds legs (33%). However, no significant difference in weight gain or growth rate was noticed among the treatment groups. The finding suggests that trimming of cheliped legs reduces cannibalism among the crabs without affecting growth performance.

Sustainable intensification of food production from pokkali farming system through cage farming

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Keywords: Cage culture, Finfish, Pokkali, Paddy, Shrimp

Pokkali is a traditional farming system of Kerala, in which paddy and shrimp farming are alternatively carried out in the same field, existing in few locations along west coast of southern India. Pokkali fields have connectivity with brackishwater creeks and hence the salinity varies routinely. The salinity comes down to 0 ppt during monsoon and rises up to 25 ppt during peak summer. Lack of suitable machinery for land preparation and harvesting of paddy invite high labour costs. Widespread attack of white spot syndrome virus (WSSV) made farmers refrain from more lucrative shrimp cultivation abandoning most of the pokkali fields. Ten to fifteen percentage of all the pokkali fields are covered by long water channels and deep water logged sluice pit near the sluice gate. They lie unutilized from June till November though they are suitable for euryhaline high value finfish farming. The remaining fields with pokkali cultivation in high water table conditions (up to three to four feet) are good source for finfish farming as well. The local indigenous fishermen used to catch the fish species in the area during this period. Hence utilization of these unutilized resources for open fish farming till commencing of the license period (November 15) is practically impossible. In this context, rearing of fish in cages and hapa nets in controlled conditions till the end of the license period is proposed in the water channels and sluice pit area of pokkali fields in order to utilize them for increased food production and subsequent income generation. Pokkali farmers were trained by ICAR-Krishi Vigyan Kendra (KVK), of Central Marine Fisheries Research Institute (CMFRI) in pond preparation, catwalk construction, cage construction, nursery rearing, fish transportation, feeding and cage maintenance. Nursery reared mullet *Mugil cephalus*, pearlspot *Etropus suratensis* and Asian seabass *Lates calcarifer* were stocked in cages during the pokkali paddy farming period (July to October) and the culture was continued later on with alternative shrimp farming (November to April) till the harvest period (April).

New concept of "farm gate market" was field tested to avoid middlemen and ensure maximum profit for farmers and quality produce to the consumers. A total of 350 kg fish were sold at the rate of ₹500 from 1 ha pokkali field over and above the regular produce of paddy (600 kg) and shrimp (200 kg). The combined revenue from paddy-shrimp field was ₹50,000 per ha. Optimum utilization of underutilized farming area by integrated finfish farming could generate an additional income of ₹10,00,000 per ha. The income generated showed the viability and reproducibility of the model which received national attention. Several agricultural agencies such as Agricultural Technology Management Agency (ATMA), Fish Farmers Development Agency (FFDA) functioning in the district have now come forward to replicate the model.

Scope of low volume cages in open water brackishwater finfish aquaculture

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Keywords: *Cage Aquaculture, Low volume, Open water*

Opportunities in brackishwater finfish aquaculture remains to be optimally utilized as in the case of brackishwater finfish cage aquaculture. High volume low density cages are generally operated in marine environment. Low volume cages are found feasible for brackishwater areas and offer multiple benefits to the stakeholders due to their lower initial investment, ease of fabrication, setting, management, higher productivity and profitability. Widespread adoption of low volume brackishwater cage culture, demonstrated by the Central Institute of Brackishwater Aquaculture (CIBA), Chennai will have a significant reflection on increasing the overall brackishwater finfish production in the country. A case study by CIBA on the low volume cage culture of Asian seabass *Lates calcarifer* in participation with a fisherman family from Kerala was carried out. In the study, a low volume cage, 1.5 x 1.5 x 1.3 m was used to stock 100 fingerlings of Asian seabass (average weight 8 g). Trash fish obtained from the Chinese dip net operated by the family were used to feed the fish. Feeding was done twice daily to satiation using chopped fish. For controlling cannibalism, grading of the fingerlings was carried out twice in the initial phase of culture. Partial harvesting was carried out from the 8th month onwards. After 11 months of culture, a total fish production of 50 kg with 50% survival was obtained. The fishes were sold in the local market for ₹400 kg. The productivity of the low volume cage was 17.77 kg m⁻³. The present study clearly suggest the scope of low volume cage farming as a family farming unit, there by producing fish for generating alternate livelihood and nutritional security.

BS

Breeding & Seed Production



Recent advances in breeding and seed production of marine finfish

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Keywords: Broodstock, Biotechnology, Feeds, Larviculture, Seed production

A rapid growth in global marine finfish farming has been noted in recent years, with an average annual growth rate of 9.3% from 1990 onwards. This can be attributed chiefly to the development of breeding and seed production techniques that made possible a reliable supply of good quality hatchery produced seeds of many high value marine finfishes. For the expansion of sea cage farming, a good deal of research and development activities are being pursued internationally on breeding and seed production of candidate species and many innovative techniques have emerged in this sector. The chief areas of research thrust include: reproductive biology, broodstock development systems, broodstock conditioning, nutrition, hormonal manipulations, live feed as well as larviculture technologies and biotechnological interventions.

Understanding the mechanism of oocyte growth and development as well as identifying the environmental influences on egg quality have led to major achievements in improving protocols for higher efficiency of egg production and viability of progeny. The introduction of Recirculating Aquaculture Systems (RAS) facilitates breeding of many species by manipulating the photo-thermal regimes all through the year. Formulation of broodstock feeds have contributed to the successful production of viable eggs. The understanding that a number of environmental factors are responsible for the cueing and timing of reproduction has led to successful controlled breeding of many species. The innovations in microalgal culture, improvements in larviculture through greenwater technique, advances in the high density mass production of rotifers as live feed, improvements in the production and utilisation of *Artemia* and nutritional enrichment have played vital roles in the success of seed production of many species. Of late, interest in copepods as live feeds in finfish hatcheries is gaining impetus because copepod nauplii are the only acceptably sized prey for small larvae of many species of marine finfish. Even though micro-diets cannot completely replace live feeds, there have been substantial achievements in reducing the reliance on live feeds and weaning the larvae earlier onto micro-diets. All these recent research advances have paved the way for more effective and economic seed production techniques for many high value species. In addition, biotechnological interventions in areas such as hybridisation, cryopreservation, gynogenesis, surrogate broodstock and transgenic strains are also progressing towards commercialisation in the near future.

Cage aquaculture in Asia: can lessons be learned from the Norwegian salmon story?

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Keywords: Intensive cage culture, Salmon, Salmon lice, Site selection, Technology

From its start in the 1970s, cage farming of Atlantic salmon in Norway has grown considerably to a production of 1.2 million tons in 2014. Over the years mistakes were made and problems arose, like wrong location of farms and disease problems. These obstacles are mostly overcome. However, two main problems restrict further growth of the industry: control of the ectoparasitic salmon lice and escape of farmed salmon. However, lessons learned and technological developments in the entire production chain of salmon can be valuable input for the development of large scale, intensive cage culture in Asia. The presentation describes the development of Norwegian salmon cage farming; including past, present and future challenges.

Cage culture in Indonesia

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Keywords: *Cage culture, Fish production, Indonesia, Equipment*

Cage culture in Indonesia is commonly practised in freshwater and in marine or coastal waters. Freshwater fish cage culture is carried out in lakes, reservoirs and rivers; while marine or coastal fish cage culture is carried out in many areas as there are several well sheltered bays and water quality is generally good. Cage culture in freshwater can be found in almost all lakes and reservoirs in Indonesia. There are a number of freshwater fish species widely cultured in cages such as carp, tilapia and catfish. Marine cage culture can be found throughout coastal waters including Batam, Aceh, West Sumatra, Lampung, Seribu Island, Bali, Lombok and Eastern Indonesia. Marine fish species cultured in cages are grouper, barramundi, red snapper, pompano, cobia and yellow fin tuna. Most cage farms are relatively medium and large scale operations (50 - 150 cages) and well-constructed made of bamboo, wood and HDPE frames with various size (2 x 2 to 6 x 6 m) and shapes (octagonal and round). Most of the farms are shaded, with a house for storing feed, nets, other equipments and equipped with electricity and high pressure pumps for net cleaning. Fish are reared in net cages for 4 - 24 months depending on the size of the cultured species. More than 300 freshwater and marine fish hatcheries as well as more than sixteen commercial fish feed factories are now operating to support aquaculture in Indonesia. The government of Indonesia targets an increase in aquaculture production from 16.9 million tons in 2015 to 31.5 million tons in 2019. However, there are several constraints to both freshwater and marine cage culture including irregular seed supply in terms of quantity and quality, and diseases (particularly *Streptococcus* infections and koi herpes virus (KHV) in freshwater fish; viral nerval necrosis (VNN) and megalocytivirus in marine fish), as well as problems of access to market and fluctuating prices.

DNA extraction and next generation sequencing applications in caged fish farming

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Cage fish aquaculture has flourished in various parts of the world including India. Traditional breeding programs based on the phenotypic traits were used to increase the productivity in the past. These techniques are slow and therefore there is a need to implement modern molecular and genomic approaches in breeding. Recent advances in molecular biology, genomics and genotyping technologies help us in rapidly predicting breeding merits, genomic selection, disease prevention and sex manipulation, thereby increasing the productivity and ensuring sustainable protein supply for the future population. The recent introduction of next generation sequencing (NGS) methods provides tremendous insight into the genome of fishes. Genetic variation studies of model fish systems are providing crucial data on adaptation and persistence mechanisms of great relevance for biodiversity assessment. Most recently, several whole genome sequencing projects involving aquacultured species such as Atlantic cod, Pacific oyster, Atlantic salmon, channel catfish, tilapia, nori and several other species are underway. Whole genome sequences can provide detailed linkage and physical maps of the genome which can be helpful in genetic analysis. Whole genome sequencing also generates large numbers of SNPs for the analysis of traits which in turn help in molecular marker based breeding to improve the nutritional quality and the yield of fishes.

Genome analysis of fishes also involves efficient and contamination free extraction of DNA from fish tissues. The column based kits generally face the issue of “column blocking” during extraction of fish tissues. Recent development of magnetic nano particle based extraction techniques has solved this problem. These methods avoid the use of columns and lengthy centrifugation steps. This leads to pure and intact DNA which can be used for any further downstream application. The principle of extraction here is based on varying the properties of the surrounding environment wherein favourable conditions are provided for the DNA to be precipitated and bind to magnetic nano particles. The DNA is further eluted from magnetic nano particles by providing energy in form of heat in aqueous environment. The magnetic nano particle based extraction works well with most of the fish samples; be it fresh, frozen or ethanol preserved making it an efficient tool for genomic studies in aquaculture.

Hatchery seed production and cage farming of tiger grouper *Epinephelus fuscoguttatus* in Andaman and Nicobar Islands

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Keywords: Cage culture, *Epinephelus fuscoguttatus*, Tiger grouper

Groupers are generally associated with coral ecosystems and are traditionally classified under the sub-family Epinephelinae. Several species of groupers are commercially important candidate species for aquaculture and are high valued commodities that mostly cater to the live seafood market of Southeast Asian countries. In India, groupers are abundant in vast stretches of coral reefs along the entire coast including Andaman and Lakshadweep Islands. Recognizing the potential for cage culture of groupers in India, Rajiv Gandhi Centre for Aquaculture (RGCA) initiated a grouper project at the Andaman & Nicobar Islands during the year 2006 to develop technologies for breeding and grow out farming of groupers in cages in open seas. Considering the availability of broodstock at the Andaman Sea as well upon studying the market potential, tiger grouper *Epinephelus fuscoguttatus* was selected as the candidate species to initiate captive breeding and sea cage culture.

A suitable location was identified off Rutland Island in South Andaman and a sea cage facility comprising of 4 x 4 m wooden cage rafts, 3 x 3 m HDPE cage rafts and working cage platforms, was established. RGCA also leased a private finfish hatchery at Kodiaghat in South Andaman and modified it suitably to facilitate the breeding, seed production and nursery rearing of tiger grouper fry to fingerlings and juveniles. Broodstock were collected from the surrounding Andaman Seas and conditioned in the cages for breeding.

Tiger grouper brooders were maintained in the cages at a female to male ratio of 3:1 and were allowed to spawn naturally in the cages. Spawning cages were provided with 400 μ hapas to facilitate the collection of eggs. The collected eggs were transported to the hatchery facility of RGCA and stocked in cement tanks after treating them with ozone @ 1 mg for 60 seconds. The eggs hatched out after 18 h. Feeding commenced within 48 - 72 h after hatching and metamorphosis occurred 35 days after hatching. Fry of 3 cm size were transferred to nursery tanks for further rearing and then transferred to the floating net cage facility upon reaching a length of 10 cm. These were reared at the sea cage farm till market sizes of 700 g to 1 kg.

Development of a low cost recirculatory system for marine finfish broodstock maturation

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Keywords: Broodstock, Marine fish, Maturation, Recirculatory aquaculture

Recirculatory aquaculture systems provide an opportunity to reduce water usage as well as to save energy needed for water pumping. The present study was undertaken to develop a low cost recirculatory system for finfish broodstock development and their breeding. A 100 ton capacity tank was provided with different components of recirculatory system viz. rapid sand filter (RSF), ventury type protein skimmer and biological filter. The tank outlet from the bottom center was used as inlet for the recirculatory loop and connected with two 3.0 hp motors. The motor outlet was connected with RSF to filter the particulate faecal material. The sand filter was connected to the ventury type protein skimmer, which suck air naturally from the atmosphere and churn the water to remove the protein present in the water. The skimmed water was passed through a 2 ton capacity bio-filter tank, filled with oyster shell and bio-ball, before returning back to the tank. The system was provided with a loop from the top of the tank through egg collecting chamber, to the motor for re-circulating the tank water, during egg collection. The total cost of the recirculatory system components (except the broodstock tank) was ₹.4.0 lakhs. The electricity consumption per day to operate this system was 36 kilowatt. Orange spotted grouper *Epinephelus coioides* in the size range of 2 - 3 kg, collected from the wild were stocked in the tank @1 kg per cubic meter for maturation and spawning. During the 10 months of experimental period, total ammonia nitrogen (TAN) including unionized (NH_3) and ionized (NH_4^+), nitrite, pH and dissolved oxygen in the rearing water were monitored. The present recirculatory system was able to reduce the total ammonia nitrogen and nitrite by $87.33 \pm 6.43\%$ and $81.66 \pm 4.93\%$, respectively. pH of the water ranged from 7.8 to 8.1 and dissolved oxygen was always above 4 ppm. Fishes attained maturity within 4 months of stocking and spawned naturally, ten days in a month, on an average. Another marine finfish species, the Indian pompano *Trachinotus mookalee* was also stocked in this recirculatory system and attained maturity within 2 months of stocking. The present recirculatory system is working excellently for maturation of marine finfish broodstock and for repetitive natural spawning within the tank itself without water exchange. The results suggest that the present recirculatory system is able to maintain the water quality required for the maturation of brooders and their natural breeding, which might greatly help in maturation and broodstock development of marine finfish in captivity.

Advances made by RGCA in breeding and seed production of cobia *Rachycentron canadum*

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Keywords: *Breeding, Cobia, India, Seed production, Stock enhancement*

The worldwide interest and success in cobia (*Rachycentron canadum*) aquaculture has encouraged aquaculture research institutes in the country to establish experimental marine finfish hatcheries. Rajiv Gandhi Centre for Aquaculture (RGCA) established its marine finfish hatchery at Pozhiyur in the southwest coast of India during 2009. Wild collected broodstock were maintained @ 1:1 male to female ratio in 100 ton recirculatory aquaculture system (RAS). After a series of futile attempts to breed cobia both naturally and through induced breeding, successful spawning was achieved for the first time during January 2011.

A total of 24 larval rearing cycles have been carried out at the hatchery till July 2015. Cobia brooders were induced to spawn by administration of LHRHa in two doses at a gap of 48 h. The spawned eggs were collected and disinfected by 100 ppm iodine dip for 1 min. The collected eggs were estimated volumetrically. In the first larval rearing, the survival rate was dismal at 0.37% at 40 dph, with more than 30% fingerlings recording deformities. This major challenge was addressed by adopting best management techniques such as feeding nutritionally superior feeds and enriched live feed. In the subsequent cycles, the survival rate ranged from 0.091 - 15%. A total production of 1.42 lakhs of 30 dph cobia larvae in the body weight range of 0.5 - 2.1 g and total length range of 4.9 - 10 cm, was achieved from 24 breeding cycles. Probiotics were used during the entire larval rearing process. Rearing of larvae in the hatchery was continued up to 72 dph and fingerlings in the body weight range of 36 - 49 g and total length range of 16.5 - 22.5 cm were produced. A total of 41,000 nos. of cobia juveniles were stocked in the sea cage farm of RGCA at Muttom, Tamil Nadu and 68,000 nos. were supplied to fishermen/farmers in Goa, Tamil Nadu, Kerala, Karnataka and Maharashtra, for culture operations in off-shore cages. In addition, 17,000 nos. of hatchery produced cobia juveniles were also ranched in the Arabian Sea as part of marine natural stock enhancement programme, since 2011.

Micron meshed cages for nursery rearing of hatchery produced green mussel *Perna viridis* spat

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Keywords: Green mussel, Hatchery, *Perna viridis*, Seed

The Asian green mussel *Perna viridis* is a significant molluscan resource of Indian coast; as they are one of the most sought-after edible bivalves found in the subcontinent. Recent years have witnessed an increased demand for mussels especially in Northern Kerala and Goa. After the peak production of 18400 tons in 2009, farmed mussel production has stagnated around 9000 - 10000 tons per year. Large scale collection of seed from the natural mussel beds for farming has led to conflicts between mussel pickers and farmers in the past with the increased adoption of green mussel farming in Northern Kerala. Therefore, mass production of mussel seed in a technologically convenient and cost-effective manner is inevitable for increasing the mussel production. Hatchery production and nursery rearing trials of *P. viridis*, conducted at Vizhinjam Research Centre of CMFRI has rekindled the hope for developing commercially viable mussel seed production technology in India. Mussel hatchery trials revealed that a production rate of 0.1 million spat can be realised from a 1 ton capacity FRP tank within 30 - 40 days and the same number can be nursery reared to seed size (8 - 12 mm) in nursery cages within 45 days.

Hatchery produced spat of *P. viridis* having an average size of 2.14 mm anteroposteriorly (APM), 1.36 mm dorsoventrally (DVM) and an average weight of 0.001g; were harvested from the rearing tanks and were used for further nursery rearing trials in the sea. For nursery rearing trails, two types of nursery cages (mesh size of 1mm x 1mm) having dimensions of 93 and 37 cm length with corresponding diameters of 10 and 9 cm were used. The cages had a volume of 7300.5 cm³ and 9410.5 cm³ respectively. The stocking density was 100000 and 50000 spats respectively for the two cages. In the Vizhinjam Bay, nursery cages were hung from the raft system and growth was recorded on every 15th day. At the end of 45 days, spat reared in nursery cages showed significant increase in size (average of 9 mm APM, 4.48 mm DVM and 0.1 g) with a survival rate of more than 95%. Simultaneously similar sized spat were also reared in one ton FRP tanks at a stocking density of 1 lakh number per tank for 45 days; and there was no notable increment in the growth (average of only 2.7 mm APM, 1.62 mm DVM and 0.009 g). Rearing spat requires enormous amount of algae to grow them up to seed size and hatcheries have limitations in providing sufficient quantity of feed and adequate environmental conditions. Rearing of spat in nursery cages is an appropriate option in the mass production of *P. viridis* seed to make it economically feasible. Weekly cleaning/scrubbing of the cages was done to prevent silt accumulation and clogging by sponge and other epi-fauna growing on the cage, facilitating free flow of water and algae through the mesh. Seed grown in the nursery cages can be used for seeding nursery ropes for further growth.

Domestication and broodstock development of the orange spotted grouper *Epinephelus coioides* in land based recirculatory systems

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Keywords: Broodstock development, Orange spotted grouper, Recirculatory aquaculture system

The orange spotted grouper *Epinephelus coioides*, is one of the promising species for farming in India, owing to its faster growth rate, good meat quality and high market demand. The present experiment was carried out to domesticate and develop broodstock of orange spotted grouper in land based 100 t capacity reinforced concrete tank with recirculation facility. *E. coioides* (24 nos. ranging in weight from 2 - 3 kg) were collected from the wild and after prophylactic treatment, fishes were PIT (passive integrated transponder) tagged and stocked in the tank @ 1 kg per cubic meter. Fishes commenced feeding only after 20 days of stocking, once they got acclimatized. After one month of stocking, half of the fishes (12 nos.) were selected randomly and implanted with a combination of 17 α methyl testosterone (@ 5 mg per kg body weight) and letrozole (@ 0.2 mg per kg body weight) to develop male broodstock by sex reversal. The fishes were fed twice a day with squids till satiation. The feed was fortified with vitamins (E, B, C and A) and mineral mixture regularly in order to supplement any possible nutritional deficiencies in their diets. The gonad development of fish was assessed fortnightly by cannulation. Water quality parameters, salinity (28 - 33 ppt), pH (7.8 - 8.1), temperature (28 - 32°C), dissolved oxygen (4.5 - 5.4 ppm), total ammonia nitrogen (<0.1 ppm) and nitrite (<0.1 ppm) recorded during the experimental period were found to be in the optimum range. Gonadal development in female fish started after 45 days and they attained gonadal maturity with ova diameter of 450 - 500 μ m within 105 days of stocking. The hormone implanted fish were in transition stage after 30 days and in oozing condition at 60 days of implantation. Mature females and sex reversed males spawned naturally after 120 days of stocking and a total of ten spawning days were observed in a month. The number of eggs collected per spawning day was 2.75 ± 1.69 lakhs. The fertilization and hatching rates were $81.20 \pm 8.81\%$ and $86.80 \pm 6.01\%$ respectively. Results of the present experiment suggest that groupers can be domesticated and broodstock can be successfully developed in land based recirculatory system, in which environmental parameters like temperature can be manipulated for maturation of brooders. The land based recirculatory aquaculture system would enable faster broodstock development of orange spotted grouper and year round supply of brooders with natural spawning, which would greatly help in seed production of the species.

Satellite nursery rearing of Asian seabass *Lates calcarifer* : bridging the gap between hatchery and the farmer

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Keywords: Fingerlings, Production, Satellite nursery, Seabass

Seabass is considered as one of the most suitable alternate species in brackishwater aquaculture sector in view of increasing incidence of disease issues in *Litopenaeus vannamei* farming. The demand for seabass fry is roughly estimated to be 25 million per year presently, but likely to increase many folds in future because of severe set back faced in shrimp farming due to several factors. Although, captive seed production and hatchery technology for seabass has been successfully developed nearly one and half decades ago by the Central Institute of Brackishwater Aquaculture (CIBA) and subsequently by the Rajiv Gandhi Centre for Aquaculture (RGCA), private hatcheries are reluctant to take up the commercial production of this species in the hatcheries due to various factors. One such important factor is the year long maintenance of brood fishes under captivity and longer seed rearing duration to produce stockable size seed for grow out culture. While shrimp seed production require only a month to produce stockable size in the hatchery, fish seed production is a year long process and it involves various activities such as broodstock development under captive condition, breeding, larval rearing, fry production, fingerling production in the nursery and stockable size juvenile production in the pre-grow out system for grow out culture. It takes about one year to produce harvestable size seabass from hatchlings. In this situation, CIBA has initiated the concept of establishing satellite seabass seed rearing in different places by providing inputs such as fish spawns/larvae/fry, live food organisms, larval diets, technical knowhow and training to the private farmers/entrepreneurs. Till the establishment of seabass hatcheries by the private entrepreneurs, satellite nursery rearing of Asian seabass offers a promising answer to produce stockable size fingerlings/juveniles of seabass. Supply of advanced fingerlings ready for stocking in cages also provides the most critical input for seabass cage culture. The satellite seabass seed rearing technology developed by the CIBA could be a catalyst in taking the finfish cage culture forward.

Status and way forward in marine finfish seed production for sea cage farming in India

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Keywords: Broodstock, Fingerlings, Hatchery, Marine finfish, Seed

The most vital prerequisite for the development of sea cage farming is the availability of hatchery produced seeds of suitable high value marine finfishes. In India, the seed production technologies developed is confined only to three species viz. *Lates calcarifer*, *Rachycentron canadum* and *Trachinotus blochii*. The seed production of these species is presently done only by government agencies and consistent and adequate seed availability is the major constraint for the prospective cage farmers. The immediate step forward is to facilitate selected private entrepreneurs to establish commercial hatcheries for these species by imparting training on the hatchery technologies developed by R&D institutions. The development of broodstock of the concerned species is a slow process and hence the hatcheries cannot develop the required broodstock within a short time frame. Biosecure broodstock development and maintenance can better be developed as a separate sector. In this regard, establishment of a few broodstock centres with recirculation systems and photothermal conditioning facilities can be a step forward in the production and supply of fertilised eggs of different species to hatcheries as and when needed. In addition to the seed from hatcheries, a few farmers can also be trained to produce seeds by extensive methods from the fertilised eggs obtained from broodstock centres. Even though only very low survival can be expected from extensive methods by farmers, the production cost is very less when compared to intensive seed production in hatcheries and it can also supplement to seed availability. A separate nursery rearing sector can also be developed so that seeds obtained from the hatcheries can be reared to fingerlings suitable for stocking in cages. One of the prime R&D requirements is to develop breeding and seed production techniques for more number of lucrative species for farming so that cage farmers can make an appropriate choice of the species as per the local demand. Moreover, it is well established that species diversification is an essential tool for ensuring sustainability. The reproductive strategies of selected high value species, growth and feed conversion efficiencies as well as marketing strategies have to be assessed and evaluated before selecting lucrative species for seed production. In short, establishment of commercial hatcheries for finfish, broodstock centres for production of fertilised eggs on demand, development of a nursery rearing sector, hands on training for extensive larval rearing methods to farmers and intensified research on breeding and seed production of more high value species can pave the way for the supply of the required fingerlings to sea cage farming.

Induced maturation and spawning of *Lutjanus argentimaculatus* in open sea cage in the Arabian Sea

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Keywords: *Lutjanus argentimaculatus*, Induced maturation, Spawning, Seacages

The mangrove red snapper *Lutjanus argentimaculatus* belonging to the family Lutjanidae is one of the important candidate species in aquaculture as it can survive in freshwater, brackishwater and saltwater (inshore and offshore) habitats and grow up to a length of 104 cm with 14.5 kg weight. However its culture is mainly dependent on wild collected seeds. The Gonadosomatic index (GSI) and the peak reproductive activity exhibited two peaks (September and October; February and March) in an year. Considering the importance of this species in cage culture, initiatives were taken at Central Marine Fisheries Research Institute (CMFRI), for its broodstock development in the open sea cages. The brood fishes reared in the circular cage of 6 m dia were tagged with 12.8 mm PIT tags for identification and monitoring the developmental stages of each fish. The fishes were fed twice daily at 09:00 and 15:30 hrs with sardines, anchovies, squid and mussel meat @ 5% of the body weight. Vitamin and mineral supplements were also given twice a week. Cannulations were carried out once in a month initially and later at every 15 and 7 days interval to track the ovarian developments. Cannulation of reared live fishes showed that most of the specimens are males and the females developed gonads with oocyte size of 100 to 200 microns. In order to speed up maturation of ova, 50, 75 and 100 µg of GnRH for female and half of these concentration for male fishes were intramuscularly administered. The fishes without GnRH administration were treated as control. The fishes administered 75 µg GnRH showed significantly higher percentage of oocyte developments. The study showed that after three months administration of GnRH, the ova reached 340 to 420 micron. In order to conduct breeding trial, female fish having ova diameter of 540 - 580 micron and ripe males were transported to the hatchery, and were administered Human Chorionic Gonadotropin (HCG) at the rate 1000, 1500, 2000 IU kg⁻¹ for females in two split doses and half of these concentration for males. The hormone injected fishes (1500 IU kg⁻¹) spawned successfully in the hatchery and the spawning occurred (24 h after injection) in the early morning. The newly spawned eggs were 800 to 900 micron size with single oil globule having 150 to 160 micron dia. This is the first report on captive hormone induced spawning of *L. argentimaculatus* in India.

Quality seed: innovative hatchery design for healthy farming of *Mugil cephalus*

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Keywords: *Aquaculture, Farming, India, Quality seed*

The culture of many finfish species are carried out in India but the major constraint in farming is the lack of adequate supply of seed. Mariculture is gaining acceptance in India due to availability of suitable habitats and resources. Mariculture is of significant importance, meeting the subsistence protein requirements of the people of our country and significant advances have been made in mariculture of finfishes in many parts of India. 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 both in the coastal and interior regions of our country. Even though some advanced technologies have been adopted recently, there exists the problem of seed availability due to fluctuations in natural recruitment. The poor quality of seed is also a major constraint in culture of mullets.

Further, in the absence of pond grown fish broodstock, concentrated efforts for mass seed production by induced breeding have to be made at the peak of the natural spawning season. However, the availability of live mature broodfish of marine finfishes from the wild population is lacking. Our present knowledge on reproductive physiology, breeding requirement and spawning behaviour with regard to grey mullets and other important marine finfish species is meager. Therefore, intensive research has to be done to determine the exact breeding requirements of *Mugil cephalus* and develop suitable techniques for artificial propagation.

Captive breeding of lemon damsel fish *Pomacentrus moluccensis* in Andaman and Nicobar Islands

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Keywords: Broodstock, Embryology, Marine ornamental fishes, Organogenesis, Pomacentridae

The Marine Research Laboratory (MRL) of Fisheries Science Division, ICAR-Central Island Agricultural Research Institute (CIARI), Port Blair initiated research in captive breeding and seed production of marine ornamental fishes as a conservation measure. Successful captive breeding of the lemon damsel *Pomacentrus moluccensis* has been achieved at MRL, ICAR-CIARI, Port Blair for the first time in India. The present study describes the broodstock management and embryology of *P. moluccensis* in captivity. Nutrient rich broodstock diet including fresh squid meat (09:00 hrs) and shrimp meat (13:00 hrs) in the morning hours and enriched live adult *Artemia* (17:00 hrs) in the evening hours was given in required quantities. Initial breeding of *P. moluccensis* was observed within 36 days of captive rearing and broodstock management. Water quality parameters in the tanks were maintained at: temperature $26 \pm 1^\circ\text{C}$, salinity 34 ± 1 ppt and pH 8 ± 0.2 with a photoperiod of 12 h (06:00 to 18:00 hrs). Incubation period was observed to be 3 - 4 days at $29 \pm 1^\circ\text{C}$. The newly laid eggs were white in colour and elliptical in shape with an average length of 1.0045 ± 0.0117 mm and average width of 0.4611 ± 0.0083 mm. The embryonic developmental stages were recorded based on the morphological characteristics and the time elapsed for each stage. Rapid cleavage with first division after 20-30 min post-fertilization was observed. The notochord formation began on the second day with commencement of organogenesis with an average yolk material of 0.1508 ± 0.0008 mm. The heart started beating and blood circulation began 36 - 40 h later. Eyes were clearly observed on the end of second day. Pigmentation on the body was observed on the third day with frequent twitching movement of tail around 60 h post-fertilization. The embryo started to hatch after 70 - 72 h incubation. Hatching occurred on the night of the third day of incubation. The larvae were found to be atrial type with mouth observed to be open in all the larvae. The fast growth rate of captive bred marine ornamental fishes which reaches marketable size within 5 - 6 months has attracted young entrepreneurs to adopt the technology in Islands. Unavailability of local market and expensive freight charges to airlift live fishes to mainland are some of the factors limiting the extension of this technology.

Captive breeding of skunk clownfish *Amphiprion akallopisos* in Andaman and Nicobar Islands

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Keywords: *Amphiprion akallopisos*, Broodstock, *Heteractis magnifica*, Larviculture, Pomacentridae

Marine ornamental fishes belonging to the family Pomacentridae fetch good price in marine ornamental fish trade owing to their colour pattern, hardiness, adaptability in controlled conditions, acceptability of feeds and are among the common marine fishes of ornamental value found in Andaman and Nicobar Islands. Marine Research Laboratory (MRL) of ICAR - Central Island Agricultural Research Institute (CIARI) successfully bred the skunk clownfish *Amphiprion akallopisos* belonging to the family Pomacentridae, for the first time in the Islands. Mature brooders were collected by scuba diving from North Bay, Port Blair along with their associated anemone *Heteractis magnifica*. They were introduced into the broodstock maintenance facility after proper quarantine and were fed with squid meat and shrimp meat at morning and evening hours. *A. akallopisos* brooders maintained at 29°C first bred in captivity after 45 days of rearing. The eggs were found attached beneath the sea anemone and the fishes showed parental care by fanning and fluttering the pectoral fins and mouthing to remove the dead or weakened eggs and dust particles. The parents and anemone were removed when the egg colour turned silvery with black eyes. The fecundity was around 550 - 600 eggs and larval survival was found to be 40%. The larviculture was also done at 29°C in the same tank with *Nanochloropsis oculata* and super small (SS) type rotifer *Brachionus rotundiformis* as first feed. The larvae were fed subsequently with S and L type rotifer *Brachionus plicatilis* and *Artemia* nauplii before shifting to shrimp and fish meat. Further egg laying was observed after 10 - 15 days leading to greater survival of larvae in successive rearing (upto 50%). Further attempts are being undertaken to breed these marine ornamental fishes in low salinity waters so as to utilize the tsunami affected areas of Andaman and Nicobar Islands for developing marine ornamental fish hatchery and to transfer the technology to unemployed youth.

Genetic stock structure investigations on *Metapenaeus dobsoni* from Indian coast using mitochondrial ATPase 6/8 genes

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Keywords: Cage culture, Genetic differentiation, Genetic stock structure, *Metapenaeus dobsoni*, Shrimps

Metapenaeus dobsoni is a potential candidate species for cage aquaculture in combination with other species of shrimps like *Penaeus monodon*, *Fenneropenaeus indicus* and *Penaeus semisulcatus*. In view of this, a genetic stock structure investigation was carried out using mitochondrial ATPase 6/8 genes in *M. dobsoni* collected from its range of distribution along the Indian coast. A total of 109 samples were collected from Mumbai, Goa, Mangalore, Kochi, Chennai and Visakhapatnam and a 900 bp region of mitochondrial ATPase 6/8 genes was amplified and analyzed in all the collected individuals. There were 74 haplotypes with a very high haplotype diversity value of 0.94. Highest genetic diversity was observed in samples from Visakhapatnam whereas the lowest genetic diversity was observed in samples from Kochi. The most common haplotype was found in 25 individuals. Overall genetic differentiation (F_{st}) value was significant (0.9) between populations. Pair-wise F_{st} analysis revealed that west coast samples (Mumbai, Goa, Mangalore and Kochi) were genetically differentiated from east coast (Chennai and Visakhapatnam) samples showing the presence of two well differentiated haplogroups. The presence of significant genetic differentiation between east and west coast samples indicate that they belong to two separate stocks and hence should be managed separately. These two stocks could be further studied for their growth and reproductive performance and the best stock could be selected for cage culture along with other shrimp species. Geographical or oceanographical barriers might have caused restricted gene flow between east and west coast populations triggering their evolution into separate stocks.

Captive maturation of Asian seabass *Lates calcarifer* in open sea floating cages at Visakhapatnam, Andhra Pradesh

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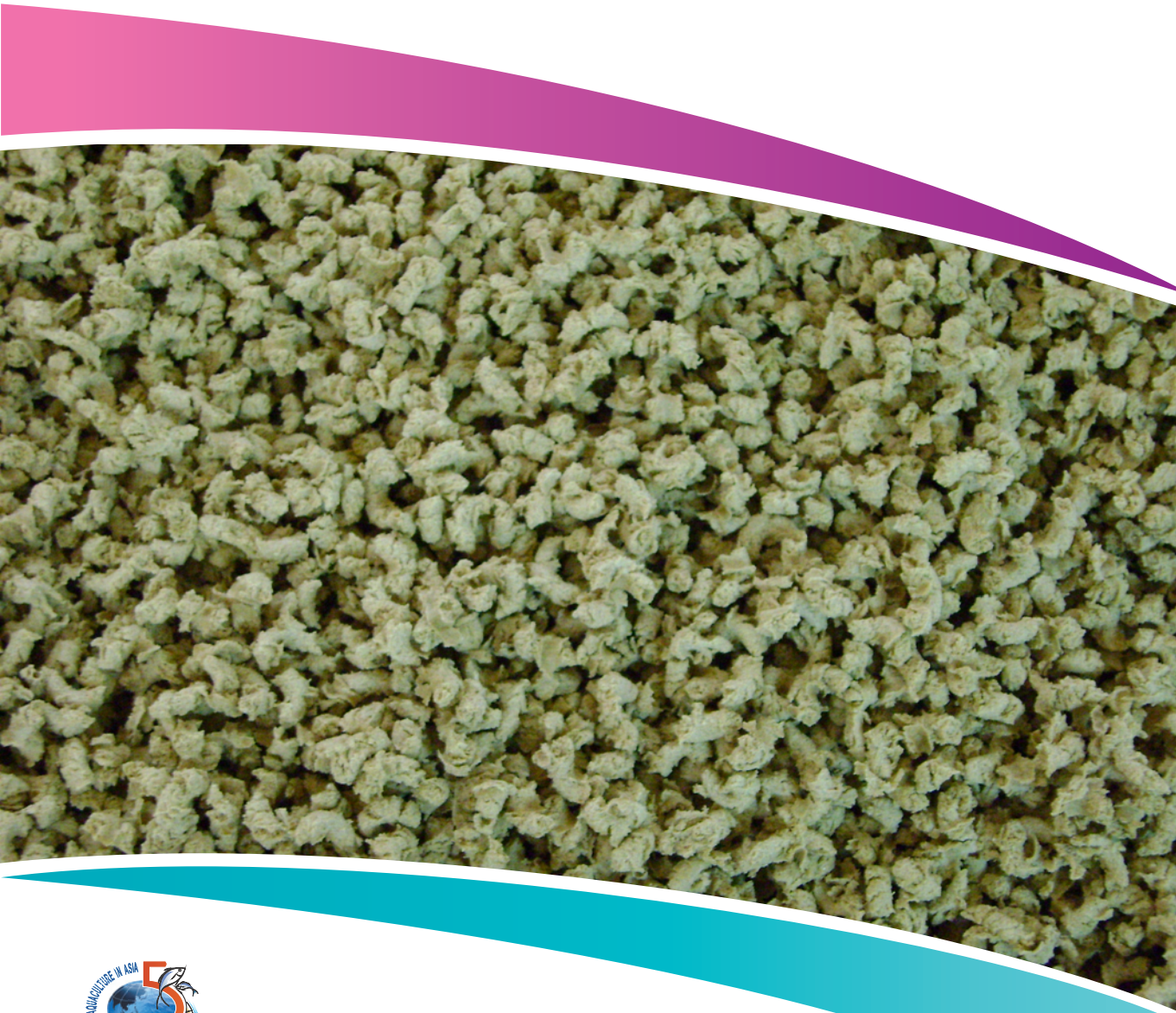
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Keywords: Asian seabass, Broodstock development, Cage culture, *Lates calcarifer*

About 10,000 hatchery produced seabass seeds (mean total length 55 ± 0.46 mm and weight 1.19 ± 0.07 g), procured from Rajiv Gandhi Centre for Aquaculture (RGCA), Sirkali, Tamil Nadu, were stocked in two hapas (6 m dia with 4 m depth) erected in 15 m dia floating cage, moored at 10 - 12 m depth in the Bay of Bengal for nursery rearing in March 2010. Mixed feeding strategy was followed in this trial by feeding with *Artemia* flakes, live *Artemia* (3 days old) and shrimp feed at different times and different quantities. After 45 days, survival was 92% with mean size at 78 ± 3.28 mm TL/ 3.53 ± 0.11 g weight. All the surviving fingerlings were released into 15 m dia cage and reared up to 149 days. Juveniles were fed with *Acetes* (5 - 7% of biomass), shrimp feed (1 - 2% of biomass) and trash fish (4 - 6% of biomass) from 46 to 149 days. After 149 days, survival was 81% and the fish attained size of 198 ± 32.02 mm TL/ 113.75 ± 57.05 g. However, due to very rough weather, cage structure collapsed necessitating partial harvest. The fishes which survived (130 nos.), were stocked in tank for 30 days and then transferred to a smaller floating cage of 6 m dia and 4 m depth and were kept for broodstock development along with broodstock of grouper *Epinephelus coioides*. Fishes were fed with squid and oil sardine at 5% of biomass and were reared from 6 to 32 months. Fish attained sizes of 372.4 mm TL/0.720 kg at 300 days; 432.3 mm TL/1.23 kg at 540 days; 526.6 mm TL/1.96 kg at 780 days and 600 mm TL/3.9 kg at 960 days. Only 3 animals survived during the 32 months rearing period. The two fishes which died during the experimental period of 24 months of rearing in cage were examined for gonadal maturation and were found to be immature females with gonads in developing stage. The remaining three fishes were also examined for gonadal development, post-rearing and were found to be females with maturing gonads. The results of this experiment offers a scoping study for broodstock development of *Lates calcarifer* in floating cages in the sea.



Nutrition & Feed



Indian aquaculture feed industry and its support to cage farming

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Keywords: Cages, Extruded feeds, Hatcheries, Species

The U.S Soybean Export Council (USSEC) runs a worldwide aquaculture activity called the Soy-in-Aquaculture Program, and has been instrumental in demonstrating and developing the commercial aqua feed industry in India based on successes obtained in other parts of the world. Most of India's fish culture systems still use nutritionally poor, agri-byproduct based, mash feeds for feeding fish with high FCR's, which cannot support cage farming systems. However, at least 25% of the inland, pond based fish farming sector in India has adopted the use of pellet or extruded floating feeds. Modern feed mills in India obtain process and formulation know-how from their foreign partners who largely operate in Asia. They can produce nutrient dense, high fat feeds suited for marine species and all plant protein feeds for freshwater fish species. High precision extrusion machinery is imported and is capable of producing feed sizes ranging from 1 to 15 mm.

USSEC has played a major role in carrying out commercial feeding demonstrations to show better returns on investments when modern feeds are used. After end users (farmers) were convinced, the capacity building phase for manufacture of quality feeds resulted in the development of 14 feed mills with an installed capacity of 1.5 million tons per annum. The current capacity utilization is only 45% because demand generation is rather slow. More fish species, more transformations from traditional methods to feed based methods, system diversification from pond based systems to cage systems and utilization of different aquatic systems (freshwater, brackishwater and marine systems) will create demand for feeds. USSEC has successfully established the LVHD (low volume, high density) systems for freshwater fish and OCAT (ocean cage aquaculture technology) for marine species in different parts of Asia. However an open ended question still needs to be answered as to why commercial cage farming in India is not progressing. One visible constraint for development of cage systems in India seems to be lack of commercially operating hatcheries for different fish species and possibly policy support.

Global scenario of feed and nutrition in cage culture

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Keywords: Aquaculture, Feeds, Functional feeds, Innovation

Seafood represents the largest protein source globally, and demand is expected to increase in the coming years. This represents tremendous potential for the aquaculture industry, and farmed seafood is projected to grow at nearly 4% annually between 2013 and 2020. Nearly one fifth of this farmed seafood production is represented by tilapia, salmon and shrimp. A key contributor to successful aquaculture is the availability of high quality feed. Functional feeds not only promote growth, but improve health and immunity, induce physiological benefits and are economically and environmentally viable. Dried fish meal is a major component of traditional fish feed. The harvest of low value fish species for conversion to fish meal has been recognised as environmentally unviable in the long run. It is therefore important to identify alternative sources of inexpensive protein in order to ensure the long term sustainability of aquaculture. EWOS has been working towards the development of alternatives to fish meal in feeds. Recent formulations have cut down the fish meal component in feeds from nearly 60% to about 30%. Another focus area with functional feeds is the management of health, e.g. the management of early mortality syndrome (EMS) in shrimp. The library of nutritional and health improving compounds being developed also has wider applications beyond current target species.

Development of marine finfish farming and the application of INVE micro-feeds and health products in marine finfish hatchery production in Vietnam

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Keywords: *Grow out, Hatchery, Marine cage culture, Vietnam*

Vietnam has great potential for marine aquaculture development with 3,200 km of coastline, large areas of brackish and marine waters, and tropical climate. Marine finfish culture has been a traditional aquaculture practice for many centuries, but the production has shifted to commodity, market oriented industry, only since the late 1980's. Despite high market demand, commercial marine finfish farming in the early stages experienced slow development due to limitations of capital investment, know-how, cheap fresh fish as feed, and the biggest bottle-neck, fingerling supplies. Marine finfish farming has tremendously developed in Vietnam in the last decade, thanks to successful establishment as well as techno-transferring of hatchery production of barramundi, pompano, groupers and cobia to local hatcheries. Barramundi has been successfully introduced into early mortality syndrome (EMS) affected shrimp farms to practice rotation farming models, which has helped to reduce disease problems in the farms and boosted the annual production of barramundi. Production of cobia and pompano have also increased in the last 5 years, from few hundred tons in 2010 to 2,500 tons in 2014.

Local hatcheries in Vietnam are currently capable of meeting the country's requirement of fingerlings for grow out. Broodstocks are cultured in floating sea cages or recirculating tanks with biofilter system, and fed with fresh fish and/or pellet feed. The fish are induced to spawn naturally and the fry are nursed in indoor concrete tanks. Rotifers, fed with S-parkle® and enriched with DHA Protein Selco® are used at start feedings, followed by *Artemia nauplii*, enriched with Selco®. Commercial NRD1/2® micro-feeds are used to wean the fry as early as day 10 post-hatch (ph) for barramundi, day 15 ph for cobia and pompano, and day 21 ph for groupers. GWS® dried microalga is used to establish the hatchery green water system, and many other INVE products, particularly probiotics, are widely used to control the microbial community in the tanks, as well as to improve fish health during hatchery and nursing stages.

The extension of marine fish farming industry has created new jobs and income for local farmers but has also resulted in environmental impacts as well as economic losses due to fish diseases. Thus, improving the fish health with high quality fingerlings, the use of probiotics and immune stimulants, and the application of fish vaccine(s) and vaccination are considered to be vital for sustainable development of fish farming.

Dietary phosphorus requirement of juvenile carp *Cyprinus carpio* fed graded levels of magnesium hydrogen phosphate

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Keywords: *Cyprinus carpio*, Dietary phosphorus, FCR, MgHPO_4

Soluble phosphorus (P) sources like monocalcium phosphate (MCP) and dicalcium phosphate (DCP) are supplemented in the diet of farmed fish to meet the requirement of P for maximum growth. The present study was conducted to evaluate the dietary P requirement of the common carp *Cyprinus carpio* using magnesium hydrogen phosphate, MgHPO_4 (MHP) as a novel source of P. Graded levels of MHP at 0.5, 1.0, 1.5 and 2.0%, and MCP (monocalcium phosphate, BIOFOS®, USA) at 2.0%, was added to the basal diet (control) *in lieu* of cellulose to get available P in the range from 0.4 to 0.8%. The MHP was recovered from swine manure using a pilot scale reactor with an effective volume of 0.4 m³ at Kangwon National University, Korea. Control diet comprised fish meal (20%), soybean meal (40%), wheat flour (27%), corn gluten meal (5%), fish oil (2%) and soy oil (2%) as major ingredients. All experimental diets were prepared as sinking pellets using a twin screw extruder. Available P in the diets was estimated based on the P availability of MHP, MCP and control diet, previously determined through digestibility trial. Following a 24 h fasting, 6 groups (three replicates per group) of 540 fish each, having mean body weight of 6.5 g were randomly allotted to 18 tanks (0.4 x 0.6 x 0.36 cm, effective volume 66 l). The feeding experiment lasted for 9 weeks during which each diet @ 4% of body weight was hand-fed to apparent satiety twice a day (08:30 and 16:30 hrs), 6 days per week. A recirculation freshwater system with dissolved oxygen maintained at 5.5~6.4 mg O₂ l⁻¹ was employed for the experiment. The weekly mean water temperature recorded was: 22±1.2°C, 20±1.5°C and 10±1.5°C during the first, second and third weeks of feeding, respectively. The flow rate was held at 5 l min⁻¹. Extruded pellet of 1.5 mm size was fed for the first 6 weeks and subsequently the pellet size was switched to 3.5 mm during the last 3 weeks. Fish were sampled and bulk-weighed at the beginning of the experiment as well as at every 3 weeks. Requirement of P was estimated in terms of weight gain (WG, %) and feed conversion ratio (FCR), using the polynomial regression analysis. Fish group fed the control diet showed the poorest WG and FCR, while the best values were observed in fish fed MCP (p<0.05). The WG of fish groups fed MHP above 1.0% was not significantly different, but the lowest FCR was found in fish fed MHP above 1.5%. Protein efficiency ratio (PER) of fish was found insignificant between the fish groups fed MCP and MHP2.0. The optimum MHP level in diet was found to be 1.85% in terms of WG. Regression analysis revealed the best WG and FCR at 0.66 and 0.71% of available P, respectively.

Evaluation of brewery waste based feeds on growth, feed utilization and body composition of cage reared striped catfish *Pangasianodon hypophthalmus* in a tropical reservoir in Maithon, Jharkhand

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Keywords: Brewery waste, Floating feed, *Pangasianodon hypophthalmus*, Sinking feed

Three isocalorific (gross energy, GE: 18.15 ± 0.2 KJ g⁻¹) and isonitrogenous (crude protein, C.P: $28.8 \pm 0.3\%$) feeds were formulated to test the effect of replacement of soybean meal with brewery waste in feed and also to evaluate the effect of different forms (floating vs sinking pellet) of brewery waste based feeds on growth performance, feed utilization, nutrient retention and carcass biochemical composition of the striped catfish *Pangasianodon hypophthalmus*. The experimental feeding trial was conducted for a period of 60 days, in cages (5 x 5 x 2.5 m) installed in Maithon Reservoir, Jharkhand. Total replacement of soybean meal in the feed did not yield any significant difference in growth parameters, feed utilization and carcass biochemical composition of the experimental fishes. With respect to forms of brewery waste based feed, fishes fed floating feed yielded significantly higher ($p < 0.05$) percent weight gain, specific growth rate (SGR), food conversion efficiency (FCE) and protein efficiency ratio (PER) compared to groups fed with sinking feed. It was also estimated that for production of unit weight of fish, the feed cost can be reduced by 32.8% and 26.5% by feeding brewery waste based floating and sinking feed respectively, compared to soybean based floating feed.

Precision drone algorithm for feed delivery in sea cages

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Keywords: Mariculture, Multi-rotor aerial vehicle, Robotics, Sea farming

Peninsular India, with its vast and unexplored marine water spread, promises a thriving future for cage farming industry. Seed production and grow out technology for a number of fish species and lobsters have been standardized by the Central Marine Fisheries Research Institute and successfully demonstrated at different locations along the Indian coast. Nevertheless, the remoteness of cage sites and the characteristic oceanographic upheavals of tropical Indian Ocean, demands several engineering interventions that can ease the level of effort and cost required for farming in the open sea. Labour cost for the daily maintenance of farm especially that for the feeding activity, forms a major share of the working cost of the entire culture activity. Together with this, weather conditions and human slip-ups can cause breaks in the routine feeding of the cultured animals. Lack of proper feeding can cause multiple stresses like nutritional deficiency diseases, decreased immunity and increased cannibalism leading to reduction of overall production from the farm. The present study proposes an algorithm for the mobilization of a location aware broadcast feeder drone designed for cage farming. The algorithm developed can enable a robotic multi-rotor/drone to locate the cage site, identify each cage and feed the farm animal by broadcasting method. Automation of the feeding activity using a drone technology can assure regular feeding. This also ensures that feed is distributed uniformly in the cages so that all animals are equally fed, ensuring minimal loss of feed. The system can also be customized to deliver other farm inputs like medicines, vaccines and fertilizers. Though drones are currently explored for surveillance activities in farms, the idea of utilizing an aerial delivery vehicle in an aquaculture activity is a novel idea. Introduction of robotics in aquaculture can create a revolution by optimizing the precision as well as effort, thereby increasing production and profit.

Evaluation of brewers spent grain as feed ingredient in diets of GIFT tilapia cultured in reservoir cages

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Keywords: *Brewers spent grain, Cage culture, GIFT tilapia, Growth*

Dietary supplementation of brewers spent grain was evaluated for its effect on growth of GIFT tilapia cultured in floating cages installed in reservoir. The experiment was conducted in 4 x 4 m size HDPE cages installed in the Poondi Reservoir in Thruvallur District of Tamil Nadu. GIFT tilapia seeds were procured from Rajiv Gandhi Centre for Aquaculture (RGCA), Sirkali, Tamil Nadu and stocked in cages at the rate of 50 m⁻³. The floating feed was fed twice daily for a period of 4 months at the recommended rate based on body weight. The proximate composition of brewers spent grain comprised 26.02% crude protein, 6.37% crude fibre, 2.51% ether extract, 1.21% total ash and 1962 kcal kg⁻¹ gross energy. Based on the analysis of essential amino acid (EAA) composition, it was found that brewers spent grain was deficient in a few EAA notably in lysine and methionine. Optimum levels of inclusion of brewers spent grain in tilapia diets appeared to vary depending on the type of ingredients substituted and levels of other protein source, especially fish meal present in the diets. A level of 20 to 30% brewers spent grain was successfully used in GIFT tilapia diets. It was also found that inclusion levels of dietary brewers spent grain can be increased by supplementation of limiting essential aminoacids.

Effect of *Gracilaria* sap supplementation on growth, proximate composition and hematological parameters of *Labeo rohita*

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Keywords: *Gracilaria* sap, Hematology, *Labeo rohita*, SGR

The study was conducted to evaluate the effect of *Gracilaria* sap supplementation in the diet on growth performance of *Labeo rohita* fingerlings. *L. rohita* fingerlings having average weight of 250 g were stocked in fifteen FRP tanks (2 x 2 x 1m) at a density of 10 fingerlings per tank. Four different diets were prepared by supplementing *Gracilaria* sap at 5, 10, 15 and 20% levels and fed to four groups of fish T1, T2, T3 and T4 respectively, in triplicates for a period of 60 days. The control group (in triplicate) received the basal diet without supplementation of *Gracilaria* sap. Growth of fish was significantly high ($p < 0.05$) in all the treatment groups as compared to the control group. The highest net weight gain of 319.16 g was observed in T2 followed by T1 (312.31 g), T3 (311.08 g) and T4 (297.83 g). Control group fishes registered the lowest mean weight gain of 289.38 g. Other growth parameters like percent weight gain, food conversion ratio (FCR) and specific growth rate (SGR) recorded were, 127.95%, 2.54 g and 0.60% respectively in T2 followed by T3 (125.10%, 2.59 g and 0.59%), T1 (124.95%, 2.60 g and 0.59%), T4 (119.10%, 2.68 g and 0.57%), and the lowest in control group (115.69%, 2.60 g and 0.56%). The crude protein and fat levels significantly improved in *Gracilaria* sap supplemented diets. Hematological parameters viz. WBC count, RBC count, platelets, hemoglobin, MCHC, MCV and HCT were also significantly improved in all the treatment groups fed *Gracilaria* sap supplemented diets.

Efficacy of formulated feeds on growth and body composition of *Etroplus suratensis* reared in cages

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Keywords: Cage culture, Formulated feeds, Growth, Pearlsplit,

A six month onfarm feeding trial was conducted in cages to evaluate the efficiency of three formulated feeds on growth performance and body composition of the pearlsplit *Etroplus suratensis*. Feed one (F1) and two (F2) were inhouse formulations and feed three (F3) was a commercially available pellet meant for freshwater carps. A total of 1350 fishes with an average weight of 20 ± 2 g were distributed into three different treatment groups, each in triplicate and each replicate had 150 fishes stocked in cages with dimensions $2 \times 2 \times 1.5$ m. The fish were sampled and weighed at monthly intervals and at the end of the feeding trail, growth parameters were assessed in terms of weight gain (%), specific growth rate (SGR), average daily growth (ADG), feed conversion ratio (FCR), feed efficiency ratio (FER) and protein efficiency ratio (PER). The feed one showed significantly ($p < 0.001$) higher weight gain (%), ADG, and SGR than the feeds two and three. The FCR of F1 was significantly ($p < 0.001$) higher than the other two feeds. Significantly ($p < 0.005$) higher PER was obtained in experimental fishes fed with F1 and F2. F1 and F2 exhibited similar FER, which was significantly ($p < 0.001$) higher when compared with the carp feed (F3). Feed one showed better growth when compared with the feed meant for carps (F3). Feeds one and two were formulations based on optimum macronutrients requirements (protein and fat) derived from an indoor nutritional evaluation in *E. suratensis*. Formulated feeds based on scientific evaluation of gross macronutrient requirements are efficient and cost effective when compared with application of readily available commercial products. The study stresses the need for species specific feed products for application onfarm for effective return on investment.

Growth response of spiny lobster *Panulirus homarus* fed on formulated experimental diets under confinement

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Keywords: *Compounded feed, Growth response, Panulirus homarus, Organoleptic quality*

Spiny lobster culture in India presently is on an experimental scale, except for some small scale activities on lobster fattening using live feeds conducted in small to large sized sea cages along different maritime coasts. Lack of technical know-how to produce seeds and dearth of information on the food and nutritional requirements during different life stages of lobsters are the main impediments to large scale lobster culture. Success of intensive commercial culture of lobsters depends largely on a steady availability of seed and feed. In this study, an attempt was made to formulate a highly stable and palatable dry compounded diet for sub-adults of the spiny lobster *Panulirus homarus* weighing below 100 g (size range 103 - 114 mm). Experimental trials were conducted using ingredients derived from natural sources. Initially a palatable basal feed was prepared and due to low stability in seawater, a series of experiments were conducted further, using different combinations of binders sourced from plants as well as synthetic origin to derive a stable and palatable pellet diet. Among the 35 test diets formulated with different combinations of binders, 6 combinations of binder incorporated diets exhibited good palatability with very good pellet stability and were selected for the formulation of experimental diets. The experimental diet exhibiting maximum pellet stability ($85.55 \pm 5.94\%$) for 8 h were derived by incorporating binders in combination of sodium alginate (3%), "stick on", a commercial phytochemical (1%) and agar agar (3%). Using selected combination of binders, 6 test diets (F1 to F6) were further formulated using different concentration and combination of ingredients and efficiency of all the diets was tested based on growth response of lobsters in the laboratory for three months. The protein and carbohydrate content of the diets ranged from 41.7 to 47.6% and 14 to 18.6% respectively. Diets with mussel meal supplemented at higher percentage exhibited better efficiency than diets prepared with fish meal and hippa meal. The maximum growth per day of 0.316 g was recorded for lobsters fed with mussel meal supplemented diet, which exhibited satisfactory growth on par with live feeds in controlled conditions, with very good organoleptic qualities having natural body colour as observed in the wild. Results of the study indicate scope for the development of high quality artificial feeds for spiny lobsters.

Sodium/iodide symporter cloning and expression response to dietary potassium iodide inclusion in yellow catfish *Pelteobagrus fulvidraco*

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Keywords: Clone, Expression, *Pelteobagrus fulvidraco*, Potassium iodide, Sodium/iodide symporter

The sodium/iodide symporter (NIS), an intrinsic membrane protein involved in iodide uptake into thyroid follicular cells, plays a crucial role in iodine metabolism and thyroid regulation. So far, little information is available on NIS. The first aim of the present study was to characterize the full-length NIS cDNA in the yellow catfish *Pelteobagrus fulvidraco*, and to determine the transcription levels of NIS gene in different tissues. In addition, the supplementation of iodine may influence the transcription level of NIS. Thus, the second aim was to determine the transcription level of NIS response to dietary potassium iodide (KI) inclusion. The homology based amplification and RACE techniques were used to obtain the full-length NIS cDNA. Moreover, RT-qPCR was used to determine the transcription levels of NIS. The KI inclusion levels were set to be 0, 10, 50 and 100 mg kg⁻¹ in four experimental diets viz. KI-0, KI-10, KI-50, and KI-100, which were fed to eight groups of fish. The feeding trial lasted for 28 days. The full-length cDNA sequence of NIS obtained, was 1986 bp, including a complete open reading frame of 1824 bp, which encoded a 607 amino acid residue. Blast online analysis indicated that the amino acid sequence of yellow catfish displayed 58-72% identity as compared with other known species. A phylogenetic tree analysis revealed that *P. fulvidraco* and *Danio rerio* were in one clade. Results of tissue transcription levels revealed that the transcription levels of NIS were detected both in thyroid tissue and in extra-thyroidal organs. The most abundant transcription levels were in the thyroid tissue, followed by brain and spleen. The dietary KI inclusion significantly affected the transcription level of NIS in thyroid, weight gain (WG) and specific growth ratio (SGR) and feed conversion ratio (FCR). The transcription level in KI-100 group was significantly higher than that of others. The weight gain (WG), SGR and FCR in KI-50 and KI-100 groups were significantly superior to those in KI-0. The regression model indicated that the best dietary KI levels acquiring the optimal WG, SGR and FCR were 73.2, 63.3 and 71.9 mg kg⁻¹. The results of the present study thus implied that dietary KI inclusion at appropriate levels effectively promotes growth of yellow catfish.

Growth and plasma distribution of phosphorus and magnesium in far eastern catfish *Silurus asotus* fed graded magnesium hydrogen phosphate

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Keywords: Diet, FCR, Magnesium, Plasma, Phosphorus, *Silurus asotus*, Weight gain

A study was carried out to investigate the supplemental effect of magnesium hydrogen phosphate MgHPO_4 (MHP) in the diets, on the growth performance of juvenile far eastern catfish (*Silurus asotus*). The MHP was recovered from swine manure using a pilot scale reactor in Kangwon National University. Graded levels of MHP at 0.5, 1.0, 1.5 and 2.0% each was added to the basal diet (control) in place of cellulose to get available P in the range from 0.4 to 0.8. Basal diet supplemented with 2.0% MCP (monocalcium phosphate, BIOFOS®, USA) served as control. Following a 24 h fasting, 6 groups (three replicates per group) of 360 fish with a mean body weight of 7.2 g were randomly allotted to each of 18 tanks (effective volume 66 l). The feeding experiment lasted for 8 weeks during which each diet was fed at 4% of body weight to apparent satiety twice a day (08:30 and 16:30 hrs), 6 days per week. Fish fed control diet showed the lowest weight gain (WG) and highest feed conversion ratio (FCR). Significantly improved weight gain (WG) and FCR were found in fish groups at dietary MHP level from 0.5 to 2.0%. The best WG and FCR were found in fish fed MHP2.0, which were significantly different from those of fish fed MCP2.0. Hematocrit (PCV, %) and hemoglobin (g dl^{-1}) of control group were significantly lower than those of the other groups. The levels of phosphorus (P) and magnesium (Mg) in plasma were the highest in fish fed MHP2.0, suggesting that growth promotion by dietary MHP supplementation, would be due to the increased absorption of both P and Mg. From the present results, it was concluded that dietary MHP could be used as a good P additive in fish diets.

Suitability of cyclopoid copepod *Diacyclops* sp. from Karwar waters as a potential live feed for larval rearing of marine finfish and shellfish

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Keywords: Cyclopoid copepod, Fish and shrimp larvae, Potential live feed

Copepods play a vital role as live feed for hatchery reared fish larvae due to their high levels of docosahexaenoic acid (DHA) and other polyunsaturated fatty acids (PUFA). Cyclopoid copepod, *Diacyclops* sp. was isolated from Karwar waters and stock cultures were maintained in 1 l beakers containing *Nannochloropsis oculata*, at a cell density of 1×10^6 cells ml^{-1} . The density of the copepod was maintained at 50 nos. per 100 ml. Experimental trials were conducted to study the density of copepods fed with different algal diets viz. *Nannochloropsis oculata*, *Isochrysis galbana*, *Chlorella vulgaris* and *Chaetoceros calcitrans*. Ten egg bearing copepods per 100 ml were inoculated into each beaker with different diets. The density of copepods varied significantly for different algal diets ($p < 0.05$). A maximum density of 945 copepodites per 100 ml was observed in *I. galbana* fed copepods at 20 days of culture. Hatching rate was 80% on day 4 of culture in *I. galbana* fed copepods. Minimum density was observed with *Chlorella*. These copepods were raised to batch and outdoor mass cultures in 0.5, 0.75 and 1 ton tanks, with a density ranging from 50 to 200 nos. per 100 ml. *Diacyclops* sp. was found to be tolerant to salinities ranging from 0 to 35 ppt and was also found suitable for culture round the year. Experiments conducted using copepod nauplii as feed for shrimp post-larvae, fish fingerlings and juveniles revealed that the maximum and minimum growth rates recorded were 2.8 and 1.6 respectively after one month rearing in laboratory conditions. This study envisages *Diacyclops* sp. as a suitable potential live feed for rearing of larvae in fish and shellfish hatcheries.

Bacterial flora of rotifers fed with different microalgal diets in outdoor mass culture tanks

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Keywords: Rotifer, Outdoor culture, Microbial loads, Algal diets

Investigations were carried out on the bacterial flora of the rearing water and the quality of rotifers cultured in outdoor mass culture tanks. *Brachionus plicatilis* and *Brachionus rotundiformis* were cultured in 10 numbers of 1 ton tanks and the physico-chemical parameters and microbial loads of water, and total bacterial and *Vibrio* loads of microalgae and rotifers during the experimental period were studied. Rotifers were fed with *Nannochloropsis oculata*, *Isochrysis galbana*, *Chlorella vulgaris*, *Chaetoceros calcitrans* and a combination of *Nannochloropsis* and *Isochrysis*. Duplicates were maintained for each diet. The study revealed that total bacterial loads were very high in the rearing water as well as in rotifers fed with *C. calcitrans*, on 3rd day of culture. The total bacterial loads were observed to be low initially for other diets but increased from 10th day onwards with partial water exchange. The study revealed significant variation in the ammonia levels and total bacterial loads of different diets ($p < 0.05$). A positive correlation was observed between the total bacterial loads of algal concentrations and that of rotifers but no correlation was observed between *Vibrio* loads of water and rotifers. The study also revealed that the total *Vibrio* loads of water as well as rotifers were very high in *C. calcitrans* fed tanks, followed by combined diet with *N. oculata* and *I. galbana*. The prevalence of *Vibrios* in rotifers was low in tanks fed with *Nannochloropsis* at a concentration of 0.6×10^6 cells ml⁻¹. Maximum *Vibrio* loads were recorded in *Chaetoceros* fed rotifers. The *Vibrio* loads significantly varied ($p < 0.05$) with days of culture and also with the algal diets. A positive correlation was observed between the total *Vibrio* loads of water and rotifers.

Growth and feeding performance of the sea urchin *Salmacis virgulata* in an indoor minicage grow out system

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Keywords: Echinoid, Feeding, Gulf of Mannar, *Salmacis virgulata*, Sea urchin aquaculture

There are atleast 22 species of sea urchins harvested for gonads from the wild for human consumption around the world. Many countries have entered into sea urchin aquaculture due to its extreme demand in Japanese and French market. Among the 264 species of echinoderms reported from Gulf of Mannar, regular echinoid diversity is known for 24 species. Gonads of regular echinoids are considered to be a delicacy around the world except for few species. In Ramanathapuram District along the Gulf of Mannar, fishermen of Manaangudi Village has been eating the sea urchin gonads as delicacy for generations. At this juncture it is imperative to know basic biological aspects of sea urchin and studying the feeding behaviour of sea urchin is one of the important attributes required for assessing its suitability for any culture attempts in captivity. In the present study, we aimed to investigate the feeding behaviour and growth of sea urchin *Salmacis virgulata* in an indoor minicage grow out system. Wild collected sea urchins from the Gulf of Mannar were acclimatized in captivity and subsequently they were starved for few days and the specimens in the size range of 33.37 ± 2.52 (test dia) were randomly distributed in to three treatment groups. A minicage structure was fabricated with PVC frame with fishing net enclosure in such a way that each replicate groups of sea urchins was in separate enclosure for monitoring and feeding them appropriately. This assembly was kept in a 2 ton FRP tank with continuous seawater flow. During the study period, an experimental diet of boiled sardine was given in three standard rations viz. 3, 6 and 9 g, each was fed to the three treatment groups, every third day. After 3 months, the final test dia and weight was compared with the morphometric data recorded at the start of the experiment. The results of the experiment showed a significant increase of 10 mm test dia in three months in almost all the treatments ($p < 0.05$). The gonadosomatic index (GSI) of the experimental animals was also studied at the end of the experiment in order to assess whether the food is used for somatic growth or gonadal growth. Among the three treatments, highest mean GSI of 10.04 ± 6.2 was recorded from the 9 g ration fed treatment while 3 and 6 g fed treatments recorded mean GSI of 6.43 ± 2.6 and 8.36 ± 4.73 respectively. The present style of feeding regime revealed that sea urchins tend to feed as much food as possible, and this in turn enhanced the GSI.

Bioencapsulation of *Artemia nauplii* using medicinal plant extracts for promoting growth in *Danio rerio* fry

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Keywords: *Artemia*, Bioencapsulation, Cytotoxicity, SGR

Herbal products have been reported to promote growth in cultured fish by improving appetite and significantly enhancing the immune system. A variety of medicinal plant products have been shown to stimulate maturation, and also have shown antimicrobial properties against microbial fish pathogens, which can aid in aquaculture without any ecological and environmental issues. Live foods are easily digestible protein rich diet for fish and shellfish, which can be cultured easily and economically. Among the live feed used in fish/shellfish hatcheries *Artemia* is the most widely used organism. It has high nutritional value and conversion efficiency. The present investigation aimed to evaluate bioencapsulation of *Artemia nauplii* with plant extracts of *Leucas aspera* for promoting the growth and survival in *Danio rerio* fry. *Artemia* cysts were procured commercially and allowed to hatch under *in vitro* conditions. The cytotoxic bioassay of the medicinal plant extracts (aqueous and methanol) was assessed in *A. nauplii*. The LC_{50} value of *Artemia* was observed at 2.5 and 1 mg ml⁻¹ of aqueous and methanol extracts respectively. *A. nauplii* were enriched for 6 h with the medicinal plant extracts and were fed to *D. rerio* fry. The experimental groups (T1 and T2) were monitored for their survival, specific growth rate (SGR), and mortality and compared with the control (T0). Significantly ($p < 0.05$) higher SGR (2.52%) was observed in T1 as compared to control 1.25% (T0). Higher survival rate was observed in T1 (92.45%) group fed with aqueous extract enriched *A. nauplii* and lower survival rate was observed in control group (86.35%). Our results clearly showed that *L. aspera* aqueous extract was more effective in enhancing the growth and survival of *D. rerio* fry than the methanol extract.

Toxic impact of coal mine effluent on nutritionally important biomolecules in different organ systems of the catfish *Clarias batrachus*

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Keywords: *Biomolecules, Clarias batrachus, Coalmine effluent*

The wetlands around the Rajrappa Coal mine Project in Jharkhand under the Central Coalfields Ltd., India, got extensively contaminated due to regular discharge of mining waste water. Unaware of the toxic effect, the economically weaker residents of the area regularly use these polluted waters to cultivate edible fishes. Excessive contamination has caused serious health hazards to the aquatic fauna including fish. These contaminated fishes might cause biotransfer of xenobiotics to higher trophic levels including human. Therefore, the objective of the present study was to analyze the toxic impact of coal mine effluent on certain vital organ systems viz. brain, liver, kidney, gills, skin, muscles and air-breathing organs of the economically important catfish *Clarias batrachus* from a pond fed with coal mine effluent, using biochemical parameters. Significant decrease ($p < 0.05$) in the concentration of proteins, lipids, moisture, glycogen, nucleic acids and other nutritionally important macromolecules were observed in the tissues of the fish collected from pond receiving effluent from the mining site with respect to those of control. The significant changes observed in concentration of these nutritionally important macromolecules in most of the organ systems indicate their active role in providing continuous energy in negotiating the toxic stress and that the extensive disturbance in the metabolic processes leads to altered nutritional value of the fish.

Microalgal diversity in a tropical estuarine ecosystem with special reference to its potential use in finfish and shellfish larviculture

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Keywords: Diversity indices, Isolation, Microalgae, Nutritional profiling, Tropical estuary

Marine microalgae are floating microscopic unicellular plants in the size range of 2 to 20 μm which are generally free living and pelagic. Many of the microalgae have immense potential in aquaculture as a means of enriching zooplankton for feeding fish and other larvae. In addition to protein and energy supply, they provide other key nutrients such as vitamins, essential polyunsaturated fatty acids (PUFA), pigments and sterols, which are transferred through the food chain. Development of marine finfish larviculture is constrained by the complex food and feeding behaviour of the larval stages. The challenges and hurdles in larval fish nutrition hinder progress in hatchery technology. Microalgae play vital role to meet the nutritional requirement of many of the finfish and shellfish larvae. Apart from the routinely used microalgae in aquaculture, several potential microalgal species occur in natural waterbodies like backwaters and estuaries, which could be explored for fish larval nutrition. The objective of the present investigation was to assess the microalgal diversity in a tropical estuary *i.e.* Muttukadu Backwaters in Kanchipuram District, Tamil Nadu and further to attempt species identification, isolation and nutritional profiling of selected species. Weekly samplings were carried out from three sampling stations during the month of May to July 2015. The salinity gradient and high percentage of primary nutrients in the Muttukadu Backwaters support diverse species of flora and fauna. The qualitative distribution and spatial variation of microalgae along the backwaters was studied. During the study, microalgal groups belonging to 16 genera were recorded from the three sampling stations. Microalgal groups identified mainly belong to Bacillariophyceae (7 genera), Cyanophyceae (5 genera) and Chlorophyceae (4 genera). Unidentified species were also recorded from all the stations. Diversity indices *viz.* Shannon diversity index, Simpson diversity index and Margalef diversity index were estimated. The major algal species isolated belonged to the genera: *Spirulina*, *Thalassiosira*, *Chaetoceros*, *Chlorella*, *Navicula*, *Microcystis* and *Pseudanabena*. The nutritional profiling of *Spirulina* and *Thalassiosira* was also done. Further, an experiment was carried out to evaluate the potential for enriching rotifers with different species of microalgae for use in mudcrab larviculture.

Effect of biofloc on growth, proximate composition and digestive enzyme activities of *Etroplus suratensis*

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Keywords: Biofloc, Digestive enzymes, Nitrate-nitrogen, Specific growth, Total ammonia nitrogen

A biofloc based experiment was conducted comprising two treatment groups: viz. T1 - fed with wheat flour + formulated feed and T2 - fed wheat flour alone, along with one control group fed formulated diet. Each group was fed in triplicates, at 2% of fish biomass in 312 l capacity indoor cement tanks, filled with 25 l of pond water and 275 of freshwater. The tanks were left for conditioning for a period of 15 days to make it favourable for the growth of microbes to develop the biofloc. Fingerlings of pearlspot *Etroplus suratensis* having an average body weight of 9.2 ± 0.2 g were stocked @ 50 nos. per tank and cultured for a period of 161 days. Specific growth rate (SGR) was recorded to be significantly high ($p < 0.05$) in T1 (1.06 ± 0.19), followed by T2 (0.79 ± 0.12) and control (0.46 ± 0.09). Proximate composition of the fishes was significantly different ($p < 0.05$) between the treatments and control. Among the treatments, crude protein, crude fibre and crude fat were highest in T1 (55.8 ± 0.07 , 0.51 ± 0.01 , $2.54 \pm 0.01\%$), followed by T2 (54.3 ± 0.19 , 0.43 ± 0.02 , $2.24 \pm 0.002\%$) and control (53.7 ± 0.14 , 0.27 ± 0.004 , $2.37 \pm 0.03\%$). The activities of amylase, lipase, protease and chymotrypsin were also significantly higher ($p < 0.05$) in T1 in comparison to other groups. Lower pH values recorded in biofloc tanks may be attributed to the higher rate of nitrification and respiration by microbes. Besides, the addition of carbohydrate significantly reduced the total ammonia nitrogen (TAN), and nitrate-nitrogen in water. From the results, it is evident that the use of wheat flour (carbohydrate source) along with formulated feed has effectively enhanced the growth performance, proximate composition and activities of digestive enzymes in pearlspot apart from maintaining the water quality in the culture system.

Efficacy of *Chaetoceros calcitrans* enriched *Artemia salina*, *Bacillus stratosphericus* (AMET1601) and nitrifying bacterial consortium as probiotics in *Litopenaeus vannamei* culture

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Keywords: Eutrophication, Microbial Diseases, Nitrifying bacteria, Probiotics, Shrimp farming

The present study was carried out to evaluate the potential of beneficial bacterial strains on improving the shrimp gut microbiota (GIT) and reducing the ammonia and nitrite toxicity in rearing water through a laboratory scale experiment. *Bacillus stratosphericus* (AMET1601) strain isolated from marine sediment samples, showed strong antibacterial activity against shrimp pathogens. The *Nitrosomonas* sp. AMETNM01 and *Nitrobacter* sp. AMETNB03 were isolated from shrimp culture pond sediments using Winogradsky Phase I and Phase II medium. A total of 150 nos. of zoea larvae of *Litopenaeus vannamei* seeds were procured from a commercial shrimp hatchery located in Marakanam, Kanchipuram District, Tamil Nadu. The zoea of *L. vannamei* kept in the experimental tanks were fed with *Chaetoceros calcitrans* and enriched *Artemia salina* up to PL20. Subsequently, the shrimps were divided into three batches in 100 l glass tanks holding 70 l of seawater, each containing 50 nos. of post-larvae. Shrimps in tank 1 (T1) were fed with commercial feed and those in tank 2 (T2) and 3 (T3) were treated with feed supplemented with 10^5 cells g^{-1} of *Bacillus stratosphericus* (AMET1601) for a period of 40 days. After 30 days of culture, in tank 3 the ammonia and nitrite oxidizing bacterial strains viz. *Nitrosomonas* sp. AMETNM01 and *Nitrobacter* sp. AMETNB03, each @ 10^5 cells ml^{-1} were added (only once on day 31). Ammonia (NH_4^+), nitrite (NO_2^-) and nitrate (NO_3^-) levels in the rearing water in all the tanks were analyzed from day 31 up to day 40. The results revealed that probiotic treatment in tank 3 (combination of *Bacillus stratosphericus* AMET1601, *Nitrosomonas* sp. AMETNM01 and *Nitrobacter* sp. AMETNB03) was comparatively superior in terms of shrimp survival (%), individual weight (wt/pc) and microbial load, in comparison to the other two tanks. Results indicate that the use of beneficial bacterial strains in shrimp culture could aid in preventing eutrophication in aquaculture systems and could also aid in controlling microbial diseases, ultimately enhancing production.

Improved growth and reduced cannibalism in Asian seabass *Lates calcarifer* fed with estradiol enriched feed

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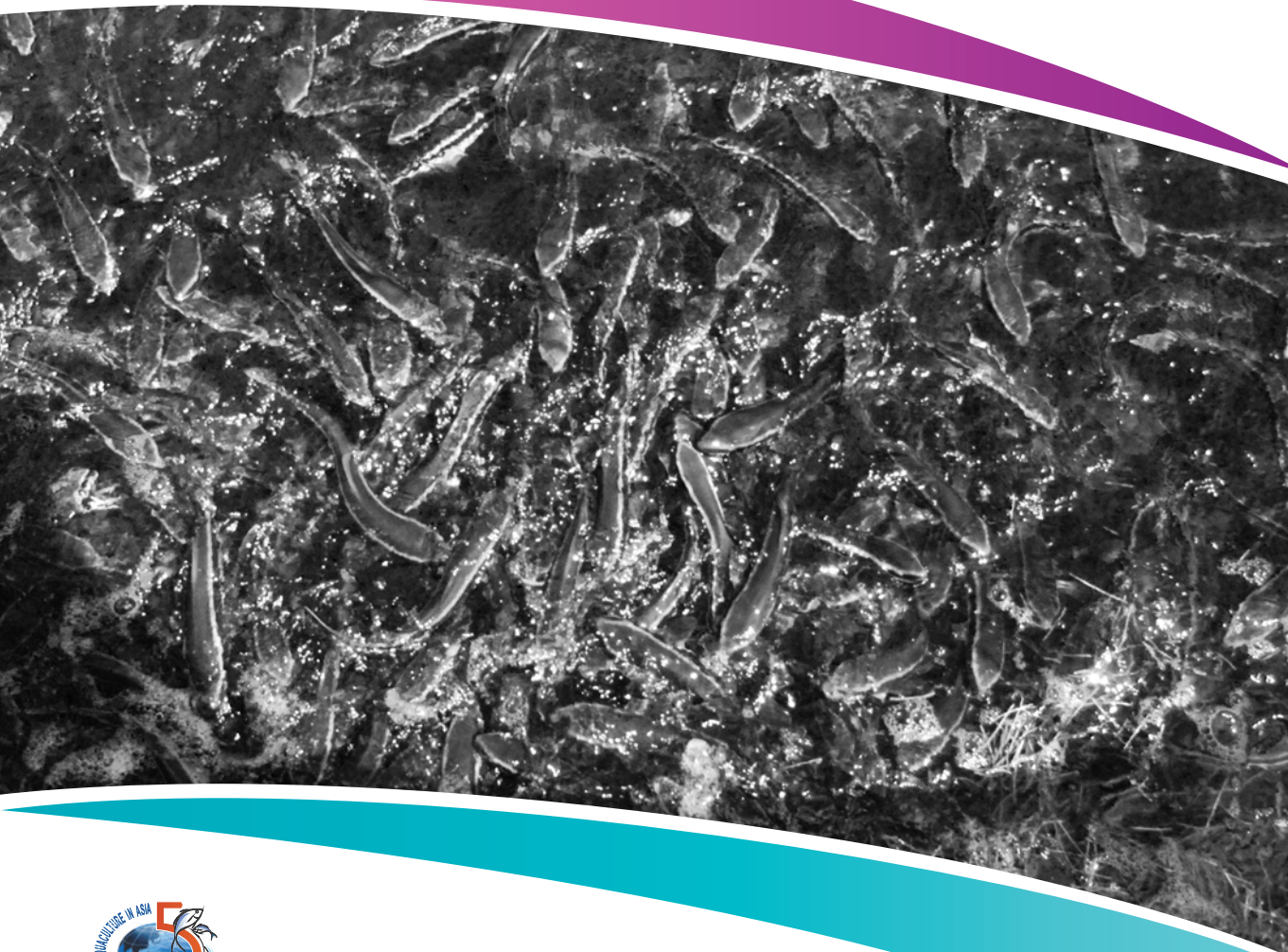
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Keywords: *Artemia*, Cannibalism, Estradiol, Seabass

Changes in sex hormone levels during early life stages in Asian seabass *Lates calcarifer*, a protandrous hermaphrodite, have definite effects on its behaviour. Levels of steroid hormones are associated with shooter emergence and cannibalism. Cannibalism during larval stages is a limiting factor in hatchery rearing of seabass. The objective of this study was to evaluate the effect of feeding *Artemia* nauplii enriched with estradiol followed by estradiol coated granulated larval feed in reduction of cannibalism. Nine day post-hatch (dph) seabass larvae were divided into three groups each in triplicate and stocked in 500 l FRP tanks @ 3 nos. l⁻¹. *Artemia* nauplii were enriched with estradiol (E₂) or 17- α methyl testosterone (17- α MT) solution for 3 h. The estradiol group was fed daily with E₂ enriched *Artemia* nauplii at a dose of 50 mg of E₂ per kg larval biomass and the testosterone group was fed daily with 50 mg of 17- α MT per kg larval biomass to observe the effect of induced masculinization on cannibalism. The control group was fed with normal *Artemia* nauplii. After 25 dph, the hormones were administered through granulated larval feed till 90 dph. Estradiol level in *Artemia* nauplii (dry weight) was measured by enzyme linked immunosorbent assay (ELISA) and was estimated to be 283 ± 2.54 ng mg⁻¹ of *Artemia* after enrichment and control showed estradiol level of 8.5 ± 0.68 ng mg⁻¹. Significant ($p < 0.05$) level of feminization was evident in protandrous seabass administered with higher estradiol level (3.5 ng ml⁻¹ of tissue steroid extract) compared to control and testosterone administered groups. Whereas 11-keto testosterone (11-KT) level (5.7 ng ml⁻¹ of tissue steroid extract) was significantly higher ($p < 0.05$) in 17- α MT group compared to control and estradiol groups. Testosterone (T) and progesterone (17-HP) levels did not show significant variation among the experimental groups. Grading was done twice weekly in all groups to separate shooters. Cannibalism and shooter emergence reduced significantly ($p < 0.05$) in seabass fed with E₂ by 35% compared to 17- α MT group and by 20% compared to control. Higher larval survival (42.5%) was achieved ($p > 0.05$) in E₂ group compared to control group (20%) on 90th day sampling. Average body weight of 5.67 ± 0.87 g was achieved after 3 months of nursery rearing when they were fed with estradiol diet, whereas fishes reached 2.48 ± 0.05 g after 3 months in control group. Sex-steroid equilibrium was altered by application of estradiol through feed, and resulted in better survival as well as growth associated with female trait. Further this approach may help to produce female seabass as broodstock, as normally natural conversion is reported only in 3 or 4 year old seabass.

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Health & Environment Management



Fish health: the Norwegian experience

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Keywords: *Cage aquaculture, Fish health, Salmonids*

Norwegian aquaculture has undergone a rapid development over the last 30 to 40 years. In 2014, 1,198.9 t of salmon and 74,300 tons of rainbow trout were produced in sea cages. The aquaculture industry experienced considerable fish health problems during this period, but these problems have been solved in different ways. From 1980-1993, the major challenges were bacterial diseases. Diseases like cold water vibriosis and furunculosis caused high mortality and economic losses. Introduction of vaccines has been an essential precondition to improve fish health, control and reduce the use of antibiotics and develop the industry. Today, vaccines are an essential part of Norwegian fish health management. Throughout the nineties, viral infections became the most important Norwegian disease problem. Outbreaks of infectious salmon anaemia (ISA) spread to main aquaculture areas and increased in numbers. ISA was defeated by important measures such as early harvesting of fish, allowing restricted movement of fish and introduction of sanitary slaughtering. Sea louse (*Lepeophtheirus salmonis*) was earlier an important fish disease problem and was defeated with chemical agents. Although new chemical treatment agents were introduced, development of resistance is today a serious issue. This has made us believe that chemicals are not the solution to control this parasite. We need to shift to a variety of non-pharmacological methods and the use of cleaner fish is an example of such a method.

Selective breeding has traditionally been used for selection of fast growing fish. Recently Norwegian researchers have found markers for disease resistance against infectious pancreatic necrosis (IPN). Salmon eggs which are selected by means of this marker have probably been an important reason why the number of outbreaks of IPN has been significantly reduced within a few years. One important lesson is that knowledge of fish health is a basic prerequisite for the success of aquaculture. In addition to this knowledge, it is absolutely necessary to have a close collaboration between industry, government and research.

Use of remote sensing in the context of cage aquaculture

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Keywords: Cage aquaculture, Carrying capacity, Oceanography, Remote sensing

For the purpose of this brief essay, the defining characteristic of cage aquaculture is that food is provided to the cultured organisms, independently of the food available in the environment itself. When organisms are cultured on the food available *in situ* (for example, in the culture of filter feeding bivalves), an important consideration is the carrying capacity of the environment, which is readily accessible to remote sensing through the calculation of phytoplankton production. However in cage culture, estimation of carrying capacity based on food requirement is not relevant, and we have to look elsewhere to see where remote sensing, supported by oceanographic information, might be of help.

We shall find that the limitations relate mainly to the dispersal of toxic metabolites and unconsumed food; to cage damage by storms; to transient water masses of temperature outside the tolerance range of the cultured species; and to the incidence of harmful algal blooms. Another consideration is the availability of essential fatty acids, for which remote sensing methods have recently been developed.

Fish health management in cage aquaculture

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Keywords: *Cage culture, Control measures, Diagnosis, Pathogens*

The growing global population, dwindling natural fish stocks, and increasing demand for quality fish products have been the major drivers for increasing fish production through aquaculture, and by 2030 the share of aquaculture in total fish production is projected to rise to 62%. However, considering the limitations posed to traditional brackish and freshwater aquaculture systems due to environmental issues, carrying capacities and disease problems, it has been recognized that cage culture, especially mariculture has many economic advantages. Over the years, cage culture has become one of the economically viable methods of large scale fish production and about 60% of coastal fish production, and more than 90% of all seabass and seabream production, is contributed by cage farming. Although cage farming has many economic advantages, like any other animal production system, diseases are one of the major limiting factors to the successful production. Both infectious and non-infectious diseases act as significant constraints to the industry, as high density rearing always paves the way for frequent disease outbreaks. Since the basic cage culture practices are similar in all the regions, disease problems encountered will largely depend on the species cultured, environmental conditions and management practices.

Among the diseases with infectious aetiologies, viral diseases are the most consequential in aquaculture systems, and in the Indian context, viral nervous necrosis (VNN) virus remains the most important viral pathogen reported from the country. Though numerous species of bacteria are reported from coastal waters, those belonging to genera of *Vibrio*, *Pseudomonas* and *Aeromonas* are considered pathogenic for aquatic animals. Except some protozoans, most of the economically important parasites in farmed fishes are ectoparasitic. Unlike closed aquaculture systems, the risk of pathogen incursion through cohabiting animals and pathogen-contaminated water is more in open cage farms and many of the biosecurity measures employed in land-based aquaculture systems will not have much relevance to cage farming. However, a thorough understanding of pathogens, disease process, diagnosis, epidemiology and control measures are essential for better health management of farmed fishes in cages. As cage farming is in a nascent stage in India, the lessons learned in dealing with disease problems and their management in land-based aquaculture systems will be of immense use in cage farming in future. In this background, this article discusses various aspects of important pathogens/diseases of farmed marine and brackishwater fishes, especially those which are recorded from Asia-Pacific region along with the challenges in managing these diseases in open cage system.

Microbial diseases of Asian seabass *Lates calcarifer*

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Keywords: Aquaculture, Infectious agents, *Lates calcarifer*, Viral diseases

Aquaculture is recognized as one of the fastest growing among the food producing industries and is expected to contribute to the reduction in gap between demand and supply of fishery products. The marine aquaculture fish production, especially of Asian seabass has increased rapidly during the past several years, owing to their high market demand and economic value. However, rapid expansion and intensification of aquaculture has led to disease outbreaks.

Among the infectious diseases, viral diseases are the most serious since they cause severe losses to production. Many viral diseases of fish have been reported worldwide, of which infection caused by Betanodavirus, a RNA virus of family Nodaviridae is a major concern. The virus has emerged as a major constraint to fish culture and is responsible for catastrophic losses in various part of the world including Europe, North America, Mediterranean countries, Asia, Japan and Australia. The disease is associated with high mortalities (up to 100%) particularly in larvae and juvenile fish species and has been reported by different names such as viral nervous necrosis, fish encephalitis, viral encephalopathy and retinopathy, by various investigators. The virus is diagnosed by microscopy, rapid and sensitive molecular methods as well as by immunological assays. Several cell lines have been developed for virus propagation and the study of infection mechanism. Bacterial pathogens such as those of the genus *Vibrio*, *Streptococcus*, and *Chlamydiales* are important infectious agents. Several bacterial outbreaks are diagnosed in fish annually, creating hurdles to the successful management of fish farms. The microbial outbreaks are focused mainly in floating cages which in turn comprise the major portion of marine fish culture. These outbreaks are usually induced by environmental fluctuation or overstocking. Parasites are also known to have harmful effects on the aquacultured animals, resulting in infections to almost all marine fish farmed in cages. Prominent among the parasitic pathogens are the protozoans, monogeneans and some trematodes. The paper discusses details of microbial infections and their management.

Diseases of grouper in sea cages in Indonesia

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Keywords: *Disease, Grouper, Parasite, Recombinant protein, Virus*

Aquaculture has contributed significantly to the Indonesian economy in the past 5 years. The total aquaculture production increased significantly from 6.27 million tons in 2010 to 14.51 million tons in 2014. Groupers are one of the most important fish species in mariculture and have been cultured intensively. The intensive culture of fish is faced with several constraints including disease. Grouper diseases in Indonesia are caused by nutritional/physiological factors, parasites, bacteria and viruses. Disease incidences and mortality due to environmental factors have also been recorded. Deformities resulting from nutritional/physiological factors are often observed in groupers and mostly happen in hatcheries. Protozoa and monogenea are most observed parasites in wild and hybrid species of groupers. Disease conditions due to *Vibrio* spp., infections are common in various species of groupers in Indonesia. Betanodavirus has been confirmed to cause viral nervous necrosis in hatchery, nursery and grow out culture in various species of grouper. At least two clusters of megalocytivirus *i.e.* infectious spleen and kidney necrosis virus (ISKNV) and red sea bream iridovirus (RSIV) clusters have been found in various species of grouper, and mainly in grow out cage. Freshwater treatments have been applied to control parasite infection with the frequency of treatment depending on many conditions. Polyvalent vaccine has been developed and applied to prevent *Vibrio* infection. Laboratory trials showed that a recombinant coat protein of betanodavirus showed high efficacy when used as a vaccine in tiger grouper to overcome infection of nervous necrosis virus. The production of recombinant proteins of megalocytivirus is in progress. Disease and mortality with blue-green colour of skin as well as small and granulated liver has been noticed in hybrid and tiger groupers. Since there is no significant pathogen found from those fishes, this disease is classified as of unknown etiology. Environmental conditions such as blooming of jellyfish in seawater have been reported in association with mortality of fish in cages. Effective freshwater treatment and carrying capacity in bay areas are important issues to be discussed.

Utilizing satellite remote sensing data and oceanographic information for identifying cage aquaculture sites and scheduling the cage maintenance activities

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Keywords: *Aquaculture, Cage maintenance, Oceanography, Remote sensing, Satellite*

Cage aquaculture relies on food artificially supplied to the cultured animals. Hence the local levels of primary production are not critical to the success of the enterprise. Rather, the risks to be avoided 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. Dispersal of toxic wastes is a function of local residence time (tides, currents, estuarine circulation where ever relevant) of the waters at the site under consideration. Here we propose a decision making protocol for site selection in cage aquaculture in accordance with the principles mentioned above.

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 northwest (NW) coast shows a tidal range of 10.90 m in Gujarat and the southwest (SW) shows 1.34 m in Kochi. 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 long over the southern latitudes and short over the northern latitudes along the coastal waters of India. However, the effect of tidal currents should also be considered for proper selection of sites for cage aquaculture and scheduling the cage related maintenance activities. Case studies have delineated the role of tidal currents along the west coast of India. Greater tidal currents were observed along the northern shelf compared with the southern shelf. The scope of open ocean cage aquaculture in north Indian Ocean is also discussed based on the analysis of residence time due to the shear-induced turbulent fluxes and other associated physical phenomena.

Experimental studies on community structure and succession of foulers on cages in Vizhinjam Bay, Kerala

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Keywords: *Biofouling, Cage farming, Community succession, Epifauna*

Biofouling on suspended cages is one of the biggest problems in sea cage farming. The communities of organisms that develop on suspended, aquaculture fish cages result in added weight and drag to the cage, reducing water flow and affecting cage behaviour and cause serious problems in cage farming. It is essential to know the succession of fouling communities for effectively controlling the biofouling. Most of the fouling organisms reproduce seasonally and if the community structure and succession pattern is known, we can plan certain management measures for effectively controlling them at the early stages of their development.

Experimental panels were made of high quality PVC pipes (15 x 15 cm), with 2 cm mesh size net having a thickness of 1.5 mm. The panels were randomly suspended using two PVC frames (1 x 1.5 m) about 0.5 m below the sea surface on the frames of our experimental cages, using nylon ropes. A total of 62 panels - 11 sets for monthly sampling, 4 sets for 3 months sampling, 2 sets for 6 months sampling and 1 set for 1 year sampling with all replicates of four were used. Wet weight of the panels as well as weight of the netting material with foulers was taken, fouling organisms were sorted into different groups, counted, weighed and preserved. The panels were analysed from February 2012 onwards. Average weight of panels was 180 g initially and on completion, it was 440 g. Average weight of net was 10 g initially which increased to 155 g in December 2012. The most common species of associates were sponges, colonial ascidians, solitary ascidians, hydroids, serpulid worms, barnacles, nematodes, oligochaetes, polychaetes, harpacticoid copepods, amphipods, brittle stars, brown mussel, rock oyster, pearl oyster, algae, isopods and small crabs. The increase in weight was mainly due to mussels, oysters and sponges. The experiment revealed a clear sequence in fouling. The dominant species in the fouling panel basically depended on the time of inception of the panel/net. The season of installation of the cage had significant impact on the dominance of the fouling species. The data showed a steady increase in community biomass and community density with duration. With respect to variations in mean number of taxa, a sudden increase in the initial months followed by a stable phase after monsoon was noticed.

Outbreak of *Vibrio alginolyticus* infection in cobia *Rachycentron canadum* cultured in floating cages

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Keywords: *Cobia*, *Cage culture*, *Haemorrhage*, *Vibrio alginolyticus*

Cobia (*Rachycentron canadum*) culture offers great possibilities in aquaculture because of its fast growth rate and high demand. Cobia farming would presumably become an emerging aquaculture sector in India in the near future. Fish cultured in floating cages become particularly susceptible to diseases. Mass mortalities of fingerlings, sub-adult and broodstock of cobia occurred during the period between April to August over the past four years in cage culture at Gulf of Mannar, Mandapam, Tamil Nadu. The outbreak of disease started with typical classical clinical signs, surfacing, corneal opacity, abnormal swimming behaviour followed by acute mortality. Grossly, haemorrhagic exophthalmoses observed in fingerlings and in sub-adults. Severe haemorrhage and congestion was observed in the entire gastric mucosal folds and the gut was empty. The gills were pale with profuse mucous secretions. Abdomen was distended with yellowish ascites fluid accumulation. Heart showed hydropericardium and fibrinous type of inflammation. Histopathologically, the gastric mucosa showed severe erosion and necrosis in the lamina propria. Haemorrhagic pericarditis and increased expression of melanomacrophage centres in kidney were observed. Severity of the infection was more in fingerlings and in sub-adults. *Vibrio* sp. isolated from the gastric lesions and from heart blood of moribund fishes was found virulent to cobia fingerlings on challenge study. After bacterial challenge, same bacterium was reisolated from moribund cobia fingerlings. The 16S ribosomal RNA of the isolate was amplified and BLAST analysis of the sequence confirmed that the pathogen is *Vibrio alginolyticus*. The confirmation was also correlated with its cultural as well as biochemical characteristics and also with pathomorphological changes in the infected fishes.

Non-specific immune response in mud crab *Scylla serrata* induced by cells or lipopolysaccharide extracts from *Alteromonas stellipolaris* strain ANT82

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Keywords: *Alteromonas stellipolaris*, Lipopolysaccharide, Non-specific immunity, *Scylla serrata*

Antarctic marine bacteria have adapted to the low temperature and oligotrophy of the environment using special metabolism and cell structure. Present study investigated the immunomodulating effect of whole cells or lipopolysaccharide (LPS) of an Antarctic marine bacterial strain, in the mud crab *Scylla serrata*. Healthy mud crabs were injected with whole cells or LPS extracts from the Antarctic marine bacterium *Alteromonas stellipolaris* strain ANT82. Antimicrobial and enzyme activities (lysozyme, phenoloxidase, superoxide dismutase, peroxidase, acid phosphatase and alkaline phosphatase) of the serum of treated animals were analysed. The above parameters were enhanced significantly ($p < 0.05$) at days 3, 6, 9 and 12 after treatment with *A. stellipolaris* strain ANT82 cells or LPS, at both low and high dosages. The non-specific immune stimulating effects of low dosage LPS were more pronounced than those of high dosage LPS and whole cells. Our results suggest that LPS extract of *A. stellipolaris* strain ANT82 has strong immunostimulant activity that could be explored as a prophylactic measure in management of bacterial diseases in the mud crab. Further studies are needed to understand the mechanism of immunostimulation *in vivo*.

Hydrobiological investigations during cage culture of striped catfish *Pangasianodon hypophthalmus* in Saroda Sagar Reservoir, Chattisgarh

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Keywords: Cage culture, Catfish, Hydrobiology, Reservoir

Saroda Sagar Reservoir (30°35'17"N; 78°48'47"E) (approx. 231 ha) in Kabirdham District of Chattisgarh State observed a recent introduction of pangus (*Pangasianodon hypophthalmus*) cage culture from 2013, wherein a battery of 99 cages (6 x 4 x 4 m) are being used. Being a supplementary feed based intensive aquaculture practice, it may have an impact on overall aquatic environment of the reservoir. The Central Inland Fisheries Research Institute (CIFRI) made an investigation during June 2015 to understand the present ecological environment inside as well as outside the cages in order to assess the impact of cage culture if any, on the overall water environment. Overall turbidity was low with slightly higher values (2.59 - 3.11 NTU) inside the cages, which might be due to suspended leftover feed and faecal matter inside cages. Sufficient dissolved oxygen, DO (7.4 - 8.0 mg l⁻¹) was recorded both inside and outside cages. Slightly higher DO was recorded inside cages, which might be due to the effect of water churning by stocked fishes. Water pH was alkaline (8.76 - 8.92) and was comparable both inside and outside cages. Slightly lower specific conductivity, total alkalinity and total hardness were observed inside cages. However, chloride level (a pollution indicator), was higher (11 - 13 mg l⁻¹) inside cages as compared to outside (8 - 9 mg l⁻¹), but both were well within the tolerable limits. Among nutrient parameters, nitrate was significantly higher inside cages (160 - 190 ppb) as compared to outside (60 - 90 ppb) which might be due to leaching of leftover nitrogenous feed. However, all the nutrient parameters were low. Biological oxygen demand (BOD) was higher within the cages (2.2 - 2.8 mg l⁻¹) as compared to outside (1.0 - 1.6 mg l⁻¹). Chlorophyll content was also slightly higher inside cages (4.3 - 5.1 mg m⁻³) in comparison to outside (3.9 - 4.4 mg m⁻³). The study revealed that though few parameters like chloride, NO₃, NH₄, BOD and chlorophyll were higher inside cages, the values were within tolerable limits with no measurable impact on the overall water quality of the reservoir. This is proved by the low plankton abundance both inside (724 - 1073 units l⁻¹) and outside cages (1065-1818 units l⁻¹). Though pollution indicator species like *Euglena* sp. were recorded within the cages, their density was low (10 - 12 units l⁻¹) and were absent outside cages. Higher plankton density outside cages may be attributed to low fish density outside cages. Higher levels of nutrients like NO₃ and NH₄ inside cages may percolate out to fertilize the reservoir which may help in higher productivity of the reservoir. However, a critical balance should be maintained for the proportion of area to be covered under cage culture; otherwise it may lead to eutrophic conditions and poor water quality of the reservoir.

Impact of net cage aquaculture on the plankton community in Kabini, a large reservoir in Karnataka

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Keywords: Floating net cages, Phytoplankton, Water quality parameters, Zooplankton

Aquaculture in net cages is a strategy to meet the growing demand for food by the world's population. However, it may lead to several impacts on freshwater assemblage and could change the community structure of the planktonic forms which are important food source of the fishes. The present study investigated the effect of cage aquaculture on water quality, phytoplankton and zooplankton in a cage culture site. Rearing of catla and rohu seeds from fry to fingerling stage was carried out in floating net cages at Kabini Reservoir in the Mysore District of Karnataka. The reservoir has an area of 6020 ha (FRL) and mean depth of 9.1 m. *Catla catla* and *Labeo rohita* were reared separately in nine cages (3 x 3 x 2 m) at the rate of 100 nos. m⁻³ with three replicates. The average stocking size was 4.8 and 5.2 cm for catla and rohu respectively. Supplementary feed (rice bran and groundnut oil cake in the ratio of 1:1) was provided at 10% of body weight thrice daily. The growth increment registered was 3.2 and 2.6 cm while the survival rate was 52.2 to 73.0% respectively for catla and rohu in 100 days.

The average density of phytoplankton at the cage site before installation of the cages was 1.58×10^3 cells l⁻¹ and during the rearing period was 1.12×10^3 cells l⁻¹. The density estimated at the reference site before cage installation and during the rearing period were 0.98×10^3 and 0.85×10^3 cells l⁻¹ respectively. The reservoir phytoplankton composition was dominated by chlorophycean forms. The blue green alga *Microcystis aeruginosa* was found to be in higher numbers during the rearing period. No significant variation was observed in the phytoplankton genera between the cage and reference sites. Zooplankton composition was dominated by rotifers and cladocerans in summer and cyclopoid copepods during monsoon in the reservoir. The density of rotifers and cladocerans was found to be higher at the culture site compared to the reference site. The zooplankton density was higher at the cage site (1.08×10^3 to 1.24×10^3 individuals l⁻¹ of water) than that of the reference site (0.64×10^3 to 0.87×10^3 individuals l⁻¹ of water) before the cage installation and during the rearing period. However, statistical analyses of the data showed that there was no significant variation in the zooplankton population between the cage and reference sites, before or during the culture period. Water temperature did not differ among stations while dissolved oxygen, pH and total phosphate were slightly lower at the rearing site.

Harvest of farm associated wild fish assemblages in estuarine cage farms: implications for farm management and livelihood

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Keywords: *Fish aggregation, Income generation, Management, Tropical cage*

Sea cage farms form attractive habitats for wild fish populations by directly providing food chain support to the fish community through excess feed and organic wastes and indirectly by enhancing plankton productivity and by providing substrate for biofouling communities. In cage farming operations, farmers realise major share of the revenue at the end of the farming season during cage harvest. Generally, financial pressure of daily life makes immediate expenditure more important than future investments. In order to meet such expenditure, fishermen in Karnataka, engaged in finfish culture using floating net cages effectively utilized the beneficial effects of aquaculture by exploiting such ichthyofaunal aggregations around net cages. The present study evaluates the characteristics of this farm associated fishing operation carried around cage farms.

Improved shore seines known as *Iliya balae* which are commonly operated near rocky areas for finfishes and shellfishes along the Karnataka Coast were used for harvesting the wild fish assemblages in the close proximity of net cages. The net panel dimension varies from 26 to 36 m in length and 2.5 - 4.0 m in depth, with 60 mm stretched mesh size. The net is encircled around the floating net cage taking care to exclude the anchor line. Once the net is positioned in water, the floats are manually pushed below the cages by diving and dragged along with the sinkers so as to cover the entire water area beneath the cages. Operation of the net is restricted to dawn or dusk during periods coinciding with the occurrence of low tides. Larger sized meshes are used to avoid harvest of smaller fishes and juveniles. The abundance and assemblage composition of wild fish around the net cages were studied. The most common families were Lutjanidae, Centropomidae, Mugilidae, Cichlidae, Carangidae and Serranidae. Aggregations were targeted under each cage individually at fortnightly intervals. Estimates of wild fish harvest in one fishing operation ranged from 15 to 40 kg of fish per cage and were dominated by family Lutjanidae. Fish aggregations around farms take advantage of waste food. Potential effects of such large aggregations of wild fish in the immediate vicinity of fish farms include increased vulnerability to pathogen transfer between caged and wild fish. Dispersal of waste and sediment management strategies followed in cage farming by using submerged electrically driven mixers to flush waste from beneath the cage or fallowing of cage culture sites as a means for controlling waste accumulation can be circumvented by adopting such seining operation under the cages, besides the added advantage of additional income generation.

Does sea cage farming influence carbon sequestration in the sea? - an assessment of carbon sequestration capacity of plankton near the cage farming sites

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Keywords: *Cage farming, Carbon sequestration, Cobia, Plankton*

Sea cage farming is emerging as a promising segment in mariculture augmenting fish production to meet ever increasing demand for marine fish. As the sector develops and expands, environmental concerns similar to shrimp aquaculture may likely to crop up, such as contribution to carbon emissions and global warming. In case of shrimp aquaculture, this concern is partly compensated by the scope of carbon burial/sequestration capacity of the aquaculture ponds. However, studies focussing on the influence of cage culture on the carbon burial rate of the plankton communities in the sea are scanty. In the Indian context, the possibilities of carbon burial by cage culture need to be explored. Hence a study was undertaken to compare the carbon sequestration capacity of planktons near the cage farm and away from the cage farm area. Plankton samples were collected using 20 micron bolting silk plankton net from three sampling stations near the cage farm of the Mandapam Regional Centre of Central Marine Fisheries Research Institute (CMFRI), located in the Gulf of Mannar and also from the reference points away from the cage farm in the open sea. The samples were quantified after filtering and drying, followed by estimation of percentage organic carbon content of the plankton. As the study is aimed to assess the total carbon sequestration capacity of the plankton community as a whole, sample collection and estimation of carbon content was carried out for phytoplankton and zooplankton together. The study would reveal influence of cage culture activity on the carbon sequestration/burial rate.

Occurrence of ichthyophthiriasis in *Pangasianodon hypophthalmus* cultured in cages in Maithon Reservoir, Jharkhand

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Keywords: Cage culture, *Ichthyophthirius multifiliis*, *Pangasianodon hypophthalmus*, Reservoir

The preliminary study on striped catfish *Pangasianodon hypophthalmus* for a period of 120 days, stocked at three different stocking densities (50, 65 and 80 m⁻³) in a battery of 16 cages (volume of 75 m³ each) was carried out at Maithon Reservoir, Jharkhand during 2015. Mass mortality of *P. hypophthalmus* in these net cages was recorded during January and February. *Ichthyophthirius multifiliis* a ciliate pathogen was identified as the causative agent by clinical signs, microscopy and histology. The important clinical signs were presence of white spots on the skin and gills of the diseased fish. Pathological signs of tissue lesions and necrosis in skin and gills of diseased fish were observed. The predisposing factor for ichthyophthiriasis is changes in water temperature (*i.e.* below 25°C), which accelerates the disease outbreak. During January and February month, the average water temperature was 18 to 19°C which might have favoured the outbreak of ichthyophthiriasis and mass mortality of *P. hypophthalmus* in the net cages. However, more studies needs to be taken up to ascertain the factors associated with disease outbreak and to formulate preventive measures.

Ecology and biodiversity of open sea cage farm at Mandapam, southeast coast of India

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Keywords: Biodiversity, Fouling, Open sea cage, Water quality

The ecology and biodiversity of open sea cage farm at Mandapam in the Gulf of Mannar was studied during 2009 - 11. The cage farm had broodstock cages for cobia *Rachycentron canadum* and pompano *Trachinotus blochii*; besides, rearing cages for seabass *Lates calcarifer*. The analysis of water quality parameters indicated no significant changes between the cage and the control sites. However, the rate of fouling was high compelling periodic cleaning and net exchange to facilitate good water exchange. The ecological aspects of cage farm and control sites, along with rate of fouling and fish aggregations in cage farming sites are presented and discussed.

Water quality parameters like salinity, pH, dissolved oxygen, chlorophyll *a* and total suspended solids (TSS) were studied from cage and control sites. A rich assemblage of 31 genera of phytoplankters and 20 zooplankton groups were identified during the study. Four groups of macrobenthos namely, bivalves, gastropods, foraminiferans and polychaetes were commonly found. The rate of fouling was found to be extremely high in the Gulf of Mannar waters and the dominant fouling community was of barnacles. Barnacles often formed a very thick mat on the cage nets and smaller the size of mesh, the barnacle infestation was more, adding tremendous weight to the cage nets, minimizing water exchange to the cages. The other major fouling organisms were rock oysters, pearl oysters, sponges, seaweeds, ascidians and *Modiolus* sp. The intruding fish species comprised silver bellies (*Leiognathus daura*), lion fish, banner fish, lobsters and shrimps (*Hippolyssmata* sp.). The crabs commonly found in the cage nets include *Plagusia squamosa*, *Hyastenus diacanthus*, *Nanopilumnus rouxi* and some porcellanid crabs. The fishes commonly found in the cage farm site comprised *Sardinella longiceps*, *S. albelli*, *Gerres filamentosus*, *Psammoperca waigiensis*, *Rastrelliger kanagurta*, *Leiognathus dussumieri*, *Siganus javus*, *S. canaliculatus*, puffer fishes, *Johnius carutta*, *Lutjanus rivulatus*, *L. fulviflamma*, *L. fulvus*, *Lethrinus nebulosus*, *Plotosus* sp., *Pempheris* sp., *Upeneus tragula*, *Parupeneus indicus*, *Alepes* sp., *Seleroides leptolepis*, *Plectorhinchus* spp., *Canthygaster solandri*, *Gnathonodon speciosus*, *Scarus ghobban*, *Therapon* sp., *Heniochus acuminatus*, *Chaetodon collare* and *Abudefduf* spp., indicating the rich aggregation of fishes in the cage farm site.

Fouling of cage nets at Villundi in Palk Bay, southeast coast of India

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Keywords: Cage culture, Fouling, India, Palk Bay

Biofouling of nets is a serious menace in open sea cage aquaculture. Intense fouling restricts water exchange and may ultimately affect the health of farmed fishes. The incidence of fouling on cage nets was studied in 2009 at Villundi in Palk Bay, southeast coast of India during an open sea cage culture of seabass, *Lates calcarifer*. The barnacles were predominant forming a complete mat on the cage net. The average number of barnacles in one square metre area of the net was 8315 nos., while the average number of oysters per square metre was 9.7. The average wet weight of the net infested with barnacles and oysters was 9.17 kg per sq. m. The studies on vertical profile of fouler infestation revealed 98 nos. of barnacles per sq. ft. in the uppermost area of the net (0 to 30 cm from the water surface). In areas of net at 30 to 60 cm from the water surface, 650 nos. of barnacles and 1 pearl oyster per sq. ft was recorded; while in the vertical layer 60 to 90 cm from the water surface, the cage net harboured 672 nos. of barnacles and 3 pearl oysters per sq. ft. The rate of fouling was found to be extremely high in Palk Bay and the dominant fouling communities were the barnacles. It was also found that smaller the mesh size of the cage net, higher the infestation of barnacles, adding tremendous weight to the cage nets and also minimizing water exchange in the cages. The high rate of fouling compels for regular cleaning of cage nets and frequent net exchanges to keep the fishes healthy.

Encrustation by bivalves in a tropical marine cage farming system

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Keywords: Biofouling, Bivalves, Tropical cage

Fouling on fish cage netting material is a persistent problem in marine cage culture systems. Intensity and diversity of biofouling varies with season, geographic location and farming environment. Therefore location specific information on biofouling communities is a prerequisite for planning and deployment of fish cages in inshore coastal waters. Cage culture of finfish is practiced at subsistence level in the inshore coastal areas of Karnataka at depths ranging from 4 - 6 m.

In the present study, the pattern and extent of biofouling was examined in the floating seabass (*Lates calcarifer*) rearing cages of 6 x 2 x 2 m installed in Mulki Estuary, Karnataka. The estuary harbours natural bivalve beds and is an important bivalve fishing area of the region. Heavy biofouling by marine macrofoulers with special reference to bivalve encrustation was observed on the webbing of fish cages moored in the estuary. The major fouling organisms observed were oysters, *Crassostrea madrasensis*, *Saccostrea cucullata* and green mussel *Perna viridis*. Among the oysters *C. madrasensis* accounted for 95% while *S. cucullata* contributed 5%. Visible vertical zonation in bivalve distribution was evident on the net panels. The oysters were distributed on the upper zone from 0.3 - 1.7 m, while 1.7 - 2 m zone as well as the cage bottom had a mixed community of green mussels and oysters. This zonation in distribution can be attributed to the salinity, which changes with the tidal cycles in the estuary. In June, two size groups of *P. viridis* were recorded on the net panels corresponding to the major spat settlement in November-December followed by the minor settlement in March - April. Shell length of *C. madrasensis* varied between 54 and 74 mm with a mean length of 62.4 ± 5.7 mm. Oyster settlement corresponded to the spat settlement in February-March.

Biofouling can influence the hydrodynamics of the fish cages by reducing the percentage of mesh opening, thus reducing the water flow and secondly by increasing the weight of the net. Mechanical cleaning of the nets by brushing, scraping or regular and frequent cleaning using water jets is advisable for removing the biofoulers in this particular site during the known spat settlement period. Oyster and mussel spat removed can also be utilized for individual oyster farming in the oyster trays and mussel ropes.

Biodiversity of macrofouling organisms in a marine cage farm at Karwar, west coast of India

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Key words: Biofoulers, Cage farm, Density, Dominance, Prevalence

A study was undertaken at a marine cage farm off Karwar on the west coast of India, to assess the fouling pattern, monthly settlement and species dominance in cage culture site during the period 2014 - 15. The net panels of mesh size 22 mm were deployed in cage site at 3 different depths during December 2014 and the study was carried out for a period of seven months. The results of the study revealed wide variation in colonisation of the biofoulers. The density of biofoulers varied between 2 - 260 cm⁻². The overall density was found to be more in bottom panels compared to the top and middle panels. The most dominant group foulers were hydroids and barnacles throughout the culture period. In the top panels, hydroids were dominant (91.67%) during the December month, followed by barnacles and amphipods. Complete dominance of barnacles were observed in the middle panel during the month of May. In the bottom panels, barnacles were dominant (93.75%) during the month of March followed by hydroids and crabs. Water quality parameters such as salinity, temperature, pH, dissolved oxygen and nutrients were also monitored during the culture period at the cage site where the panels were deployed. The results revealed that hydroids formed major contribution of the fouling organisms throughout the culture period. A significant variation in the occurrence and abundance of fouling organisms was noticed between different depths at the cage site.

Microbial quality of water around open sea cage farm sites on Arabian Coast of India

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Keywords: Cage culture, Lobster, Marine water, Microbial quality, Pathogens

The selection of cage culture site is an important criterion to achieve good productivity and produce microbiologically safe seafood. Success of cage farming depends on the quality of marine waters and periodical monitoring of water quality is one of the essential parameters. The levels of indicator organisms like faecal coliforms, faecal streptococci and pathogenic bacteria like *Salmonella*, pathogenic vibrios and *Listeria monocytogenes* are commonly used to monitor presence of indicator microorganisms and bacterial pathogens respectively in cultured marine water. Marine water samples were collected at weekly intervals for a period of 4 months from open sea cage farm culturing spiny lobster *Panulirus polyphagus*, off Somnath in Gujarat (20°53.646'N, 70°, 23.053'E; 20°53.571'N, 70°23.008'E; 20°53.271'N, 70° 23.709'E; 20°53.229'N, 70° 23.655'E). The microbial quality parameters such as total plate count (TPC), total enterobacteriaceae (TE), *Escherichia coli* (EC), staphylococci (SC), faecal streptococci (FS), *Salmonella*, *Vibrio cholerae* (VC), *Vibrio parahaemolyticus* (VP) and *Listeria monocytogenes* (LM) were determined as per the method of USDA's bacteriological analytical manual (BAM), 2014. The TPC, TE, EC, SC and FS counts of positive samples ranged from 1.65×10^1 to 3.0×10^5 , 1.0×10^1 to 5×10^4 , 4.0 to 2×10^2 , 2.0 to 7.8×10^1 and 2 to 6.0×10^2 cells g⁻¹ respectively. *E. coli* was absent in the reference site water samples analysed during the period. The overall percentage of occurrence of *E. coli*, coagulase positive staphylococci, fecal streptococci and *Salmonella* sp. were 37.50% (6/16), 18.75% (3/16), 43.75% (7/16) and 6.25% (1/16) respectively from the marine farm water samples, which indicates that the possible source of contamination is from sewage and/mammalian faecal matters. So it's further suggested that utmost precaution should be taken while selecting the site for cage culture.

Stereomicroscopic and high resolution SEM studies of gill, mouth cavity and lateral line of pompano *Trachinotus blochii* using chemical method of tissue drying

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Keywords: Cellular, Chemical method of drying, HMDS, HR-SEM., Long term storage

Although the chemical method of drying tissues for scanning electron microscopy (SEM) was developed more than three decades ago, its use for specimen preparation is quite rare in comparison to the alternative methods of tissue drying such as critical point drying (CPD) and freeze drying owing probably to perceived compromise in electron micrograph quality. We evaluated the suitability of the chemical method of drying of pompano *Trachinotus blochii* using hexamethyldisilazane (HMDS) for preliminary stereomicroscopy and subsequent high resolution SEM (HR-SEM). Juvenile pompano were fixed overnight with 2% gluteraldehyde in phosphate buffered saline (PBS) followed by dehydration with graded concentrations of ethanol. After dehydration in 100% ethanol, specimens were immersed in graded concentrations of HMDS (ending at 100%) followed by air drying and storage for several months for subsequent stereomicroscopic and HR-SEM analysis focusing on different anatomical structures such as the gill, pharynx and lateral line.

Stereomicroscopy of the dried tissues was found to immensely aid in correct grossing and unambiguous fine orientation of desired tissue points under HR-SEM. HR-SEM studies of the chemically dried specimens revealed that despite being easier, inexpensive and flexible, the chemical method compares favourably with the expensive but widely used methods, such as CPD and freeze drying, with regard to preservation of tissue texture, minimum tissue disruption and shrinkage, and fine imaging quality without artefacts. Notably, our method withstood even the high vacuum (HV) mode of SEM and was suitable for almost all types of fish tissues. The ability to observe the detailed surface structures at the cellular level such as the micro-ridge structure of the epithelial cell of the palate and skin, opening of the goblet cells in mouth epithelia, type-I and type-II taste buds on the jaw and palate, neuromast cells on lateral line, chloride cells on gill epithelium, erythrocytes on fractured gill capillary and the attachment of bacterial cells with well preserved shape and texture onto the epithelium testifies the suitability of this method for studies involving morphological development, physiological response to environmental parameters, haematology and host-pathogen interactions.

Establishment and characterization of two morphologically different cell lines from fin tissue of the pompano *Trachinotus blochii*

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Keywords: Cell line, Epithelioid cells, Fibroblastic cells, Snubnose pompano, *Trachinotus blochii*

The snubnose pompano *Trachinotus blochii* is one of the most promising fish species for aquaculture in South Asia. The Central Marine Fisheries Research Institute (CMFRI) has achieved success in the broodstock development, induced breeding, larval production and farming of *T. blochii*. Occurrence of diseases of various etiology is one of the major issues in intensive fish culture. Increase in aquaculture operations worldwide has provided new opportunities for transmission of aquatic viruses and the occurrence of viral diseases remains a significant limiting factor in development of aquaculture. However, increased awareness of disease risks, new health control legislation and better diagnostic methods, which have increased the ability to detect diseases and pathogens in fish, are helping to reduce the frequency of introduction and the spread of diseases. Establishment of sensitive, species specific fish cell lines is necessary for the isolation and characterisation of viruses, development of diagnostic reagents and for the production of material for immunological and vaccination studies. Fish cell lines are also powerful tools for studying toxicology, immunology and functional genomics in fish.

The present paper describes the establishment and characterization of two morphologically different cell lines from the fin tissue of *T. blochii*. The fin cell lines TB2F3Tr and TB2F2Tr derived by trypsinization are epithelial and fibroblastic in morphology respectively, and have been passaged over 60 times. The cell lines grow at an optimum temperature of $28 \pm 2^\circ\text{C}$ in Leibovitz-15 medium supplemented with 5 - 20% foetal bovine serum (FBS). The growth rate of cells increased proportionately with the concentration of FBS from 5 to 20%. The established cell lines have been characterized by chromosomal analysis, immunofluorescence staining for epithelial/fibroblast markers, transfection efficiency and also by sequencing of mitochondrial CO1 gene to confirm the species of origin. Furthermore, the cell lines were also subjected to ultrastructural studies by transmission electron microscopy to rule out presence of inherent viruses. The cell lines have been successfully cryopreserved and the viability of cells were found to be >80% when revived after one year of storage in liquid nitrogen.

Bacteriophage based control of bacterial infections commonly encountered in farmed flounder *Paralichthys olivaceus*

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Keywords: Antibiotics, Bacteriophage, *Edwardsiella tarda*, *Edwardsiellosis*, Flounder, *Streptococcus*, *Streptococcus parauberis*, Mortality

As the use of antibiotics in feeds has been banned in Korea and worldwide, the need for dietary alternatives to antibiotics is warranted. Bacteriophage is being considered as an alternative agent to antibiotics to control bacterial diseases owing to the high bacterial specificity and unique antibacterial properties, especially against antibiotic resistant bacteria in aquaculture as well as in terrestrial animal husbandry. In the present study aimed at search for alternatives to antibiotics against fish bacterial pathogens, we isolated and characterized bacteriophages specific for streptococcosis caused by *Streptococcus parauberis* and edwardsiellosis caused by *Edwardsiella tarda*, which have been reported as major pathogenic bacteria in aquaculture of the olive flounder *Paralichthys olivaceus*. Fish fed diets supplemented with the bacteriophages showed significantly decreased mortality, resulting in biomass gain. The results indicate that bacteriophages could form alternative to use of antibiotics in control of bacterial diseases in aquaculture.

Accurate identification of parasitic infestations for effective management and treatment in aquaculture

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Keywords: Aquaculture, Fish parasites, Identification, Management, Treatment

Diseases and parasites pose a significant threat to farmed fish and shellfish causing economic hardship for farmers. A wide variety of parasites are reported as lethal pathogens of fishes in culture conditions. The culture facilities provide good substrate for parasites and the intensive aggregation of fishes facilitates the transmission of parasites between hosts. Accurate identification of the parasite is inevitable in effective management of parasitic diseases in aquaculture. Health assessment index (HAI), prevalence and severity of parasitic infestation, histopathological alterations due to parasitic infestations and molecular identification of parasites along with the scanning electron microscopy (SEM) are the available tools for investigation on parasitic infestations in fish. The paper discusses on application of these methods for accurate identification of parasitic infestations for formulating effective management strategies and proper treatment in aquaculture.

Keratinization of epidermis in the ornamental catfish *Chaca chaca*: histological and scanning electron microscopic investigations

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Keywords: *Chaca chaca*, Keratinization, Skin, Tubercles, Unculi

Adaptive modifications in the skin of the ornamental catfish *Chaca chaca* was investigated using light and scanning electron microscopy. The dorsal body surface has characteristic elevated keratinized structures, keratinized tubercles and ridged unculiformis plaques with cornified horny projections (unculi) irregularly distributed in between mucogenic areas. The keratinized areas were distinguished by hypertrophied epithelial cells. Mucous cells, club cells and taste buds were absent. In the non-keratinized mucogenic areas, the epithelial cells were characterized by intricate pattern of microridges, mucous cells being irregularly distributed, club cells present in between the epithelial cells and taste buds generally located on epidermal protuberances. The polygonal cells in the basal layer of epidermis gradually get transformed into flattened cells as they are displaced towards the outer surface. The surface epithelial cells are dead and cornified, forming characteristic epidermal caps which are shed in the form of sheets. Periodic sloughing of the superficial keratinized layer of epithelial cells may remove silty deposits, organic debris and pathogens, thereby keeping the skin surface clean. Keratinization appears to be an alternative method of protecting the surface of skin against mechanical damage and potential attack by pathogens. Therefore, the study would be helpful to unravel the physiological adaptations of the fish with respect to specific ecological conditions. The findings would also be advantageous in better understanding of the conservation strategy of the species.

Dynamics of *Vorticella* sp. infestation in cobia *Rachycentron canadum* larvae and specific growth rate of the parasite

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Keywords: Artificial media, Cobia, Dynamics, Glass slide, *Vorticella* infestation

In one batch of hatchery reared larvae of cobia *Rachycentron canadum*, infestation by the peritrichous protozoan organism *Vorticella* sp. was observed during routine microscopic examination and was further investigated for its dynamics. The infestation first occurred on the 8th day after hatching and was most severe on the first day of observation which gradually subsided over the next 5 days before gaining a minor increment on the last day producing a "C" shaped infestation dynamics curve. The organism had the typical inverted bell shaped cell-body attached to the long and thin cylinder stalk. The number of cell bodies per stalk attached to the skin surface ranged from 1 to 32. Histopathological investigation of the infected larvae was carried out to probe pathogen attachment on the dermal surface. It was found that the stalk was only superficially attached to the fish skin without much penetration below the skin surface. In order to understand the reproduction rate of the parasite, an attempt was made with initial success, in culturing the organism on surface of glass slides immersed in glass beakers containing artificial media. In the artificial medium, the organism multiplied 22 to 32 times over a period of 48 h and the specific growth rate ranged from 1.545 day⁻¹ to 1.745 day⁻¹ with a generation time of 9 h 32 min to 10 h 46 min. With this culture method, it was possible to delineate the detailed morphometry of the parasite using SWIFTCAM image software. In addition, it was possible to visualize the contraction-relaxation cycle and telotroch production of the parasite on the glass slide surface while the parasites were inside a thin pellicle of water.

Effect of asiaticoside on the proliferative activity of epidermis during healing of cutaneous wound in the Indian major carp *Cirrhinus mrigala*

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Keywords: Asiaticoside, *Cirrhinus mrigala*, Fish epidermis, Proliferative activity, Wound healing

Cellular proliferation in the epidermis of the Indian major carp *Cirrhinus mrigala* during healing of cutaneous wound was investigated using proliferating cell nuclear antigen (PCNA) immunohistochemistry. Fishes were wounded with skin biopsy punch (2 mm²) on the dorsal side of the head and divided into two groups. First group received intraperitoneal injection of asiaticoside dissolved in 10% DMSO at a dose of 1mg kg⁻¹ body weight. Second group was allowed to heal without treatment and kept as control. The pattern of proliferation activity was uneven during the initial phase i.e. at day 1 and day 2 in both treated and untreated control group. However, there was a significant increase in proliferating epithelial cells at the wound margin in treated group compared to untreated control. At day 4 and onwards, the proliferating epithelial cells were observed in the wound gap region as well, in both treated and untreated control group. However, density of proliferating cells in the treated group did not show significant differences as compared to the untreated control. Higher proliferation at the wound margin compared to the wound gap region indicates that cells were displaced from the wound margin onto the wound gap upon their proliferation. The above finding suggests that asiaticoside could be useful in promoting wound healing by enhancing proliferative activity of epidermal cells.

EL

Economics, Livelihood & Policies



Aquaculture governance: balancing increased food production and environmental sustainability

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***Keywords:** Aquaculture policy, Legislation, Norway, Salmon*

The salmon aquaculture industry in Norway is relatively young. Since its start around 1970, the production has increased steadily and rapidly to a total production of 1.3 million tons, in 2014. During this period aquaculture legislation has evolved and matured. Today, the aquaculture industry is regulated by the Aquaculture Act. The main purpose of this Act is to promote the profitability and competitiveness of the aquaculture industry within the framework of sustainable development.

To engage in aquaculture activities requires a license. This means that aquaculture and sea ranching activities without a license are illegal. Salmon farmers need one license to produce salmon (typically 780 tons), issued by the Ministry of Trade, Industry and Fisheries, and one license from the county that in detail defines the site where the aquaculture production can take place. The process to acquire a site for production involves several authorities. The county processes the application based on comments and decisions made by the municipality, the Directorate of Fisheries regional office, the Norwegian Food Safety Authority, the Norwegian Coastal Administration and the County Governor. The Aquaculture Act has a strong environmental profile. At the same time, the relationship between the use of the coastal zone and different user interests is taken into account. The environmental and land use provisions are intended to contribute to a good coexistence between the aquaculture industry and other public interests.

The production of salmon has increased steadily. New production sites have been cleared by different counties and taken into use by the aquaculture industry. The existing site structure is therefore largely a result of the counties processing received applications, and not the result of a national area management plan. The government has recently presented a white paper with proposed means to ensure further sustainable growth in the salmon aquaculture industry. The main measures include dividing the coastline into several production areas. A rule-based system with environmental indicators will be decisive for further growth in each production area. Salmon lice have been identified to be very well suited as an indicator in a rule-based system for growth. The government will also investigate if effluents from aquaculture farms could be used as an indicator in this system. The government white paper also includes new measures to promote the development of technology for alternative aquaculture production, such as sea based closed containment farms, land based farms and open sea (offshore) farms.

Aquaculture policy and legislation in India

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Keywords: Aquaculture, Central acts, National policy

India is the second largest aquaculture producer in the world with a total aquaculture production of 4.2 million tons, of which freshwater aquaculture contributed nearly 90% with major contributions from carps followed by *Pangasius* and *Tilapia*. Shrimps were the major contributors in marine aquaculture production. The total aquaculture contributions are hardly from 15% of the total resources available and there is a very high potential for increasing aquaculture production in the country. The major issue is the lack of a comprehensive aquaculture policy at the National level. This is mainly because India is a federal Union of States comprising of 29 States and 7 Union Territories (UTs) with legislative powers for policies of land and water, which are the major requirements for aquaculture development, vested with the States and UTs. State level aquaculture policies with supporting legislations are few in number. At the Central level, Coastal Aquaculture Authority Act, 2005 is the only specific act for the regulation of land based coastal aquaculture. But there are other Central Acts which are relevant for the development of aquaculture - Environmental Protection Act, 1986; Water (Prevention and control of Pollution) Act, 1974; Wild life protection Act, 1972; Livestock importation (Amendment) Act, 2001 and Prevention and control of infectious and contagious diseases in animal, 2009. This article reviews the various State level policies on Aquaculture Development, State and Central legislations, International requirements and indicates the gaps which need strengthening for enhancing aquaculture production.

Institutional credit support for cage aquaculture in India: policy interventions

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Keywords: Cage aquaculture, Institutional credit, Policy issues

While India accounts for about 5.75% of world fish production, the share of its exports account for only 3.68% with scope for producing high value exportable candidate species. The share of inland and marine sectors in world fish production accounted for 34% and 66%, the same in the Indian context is just the reverse *i.e.* 65% and 35% respectively. It is amply clear from the preponderance of inland sector in total fish production in India, that India is not able to make use of its vast marine and coastal resources, despite having a long coastline and extensive Exclusive Economic Zone. The productivity of inland open water systems is also very low compared to their potential, though species like *Pangasius* have been introduced and farming systems like cage culture in reservoirs are being attempted on a limited scale.

Realising the need to diversify aquaculture species and practices, which is currently dependent on carps in inland sector and shrimps in the coastal/marine sector, research institutions have focussed their attention on new species, culture systems and evolved breeding and seed production and farming systems covering Asian seabass, cobia, pompano, seabreams, lobsters and crabs. Cage culture in open waters has been demonstrated to be one of the farming systems with vast potential for grow out production as well as seed rearing. Seaweed farming with floating rafts is also being practiced to a limited extent.

Though cage aquaculture is emerging as the technology of the future for India to expand aquaculture production, the package of practices are yet to be standardised keeping in view, specific species and grow out systems. Further, it needs huge investments and an enabling policy framework. Investments in the form of credit support from the formal financial system is hindered with many bottlenecks in the fronts of technology, credit and insurance, policy for use of open waters, environment and social issues. The paper analyses policy options and bottlenecks to be addressed to attract investments and institutional finance to realise the huge potential available in the form of open water cage aquaculture.

Cage aquaculture in India: legal perspectives

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Keywords: India, Legal framework, Responsible aquaculture

Cage aquaculture in India was only developed in the latter half of the first decade of the 21st century. Therefore, it is not surprising that one does not find any reference to the said activities either in the Constitution of India, 1950 or in the Territorial Waters, Continental Shelf, Exclusive Economic Zone and Other Maritime Zones of India Act, 1976. The Marine Fishing Regulation Acts of various states are also silent on this point. Further, there is very little case law that deals with how the existing legislative regime applies to aquaculture activities. This means that the interpretation of how current legal measures apply to aquaculture is complicated and uncertain.

Though the 1976 Act confers rule making powers to the central government it is not likely to be an effective tool for regulating 'cage aquaculture activities', if any, within the Exclusive Economic Zone. The competence to enact laws with respect to 'fisheries in territorial waters' lies with the state legislatures. As things stand at present no 'state' in India has enacted a legislation to regulate 'aquaculture activities' in territorial waters. Since 2007, cage aquaculture has become an integral component of Indian fisheries. It is therefore necessary that clear policies and comprehensive legal regimes are developed so as to facilitate sustainable development of cage aquaculture in India. In this context it is pertinent to examine whether the current legal framework in India is capable to address the multi-dimensional issues presented by the adoption of cage aquaculture in India and what is the way forward, in so far as the establishment of a legal and institutional framework which facilitates the development of responsible aquaculture in India.

Marine cage farming to empower fishermen self help groups in India: a perspective

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Keywords: Alternate livelihood, Cage farming, Employment generation, Self help groups (SHGs)

Cage farming of marine finfish and shellfish was first initiated in India by the Central Marine Fisheries Research Institute (CMFRI) during 2007 at different locations along the Indian coast. Later Karwar Research Centre (KRC) of CMFRI succeeded in developing farming technologies for Asian seabass *Lates calcarifer* in marine cages. The centre intensified the farming of marine finfishes viz. Asian seabass, cobia *Rachycentron canadum* and pompano *Trachinotus blochii* along the Karnataka, Goa and Maharashtra coasts. As part of expansion of open sea cage farming in India and employment generation for the fisherfolk, CMFRI initiated participatory demonstration programmes at Goa with support of the Department of Fisheries, Government of Goa from 2013 - 14 onwards in three different areas viz. Polem, Talpona and Nuem. Under this programme, three self help groups (SHGs) with 20 fishermen in each group were identified for cage farming. Demonstration programmes were conducted for all the SHGs on the technologies developed at KRC of CMFRI for cage culture of cobia, seabass and pompano. A total of 50 cages were installed by SHGs in the three places in Goa during the period 2014 - 15. Cage farming was undertaken in 6 m dia steel cages with a stocking density of 14 nos. m⁻³ for seabass, 4 nos. m⁻³ for cobia and 20 nos. m⁻³ for pompano. Technical and scientific support was extended to the groups by the Karwar Research Centre to carry out cage farming systematically. The SHGs achieved a final production of 18 tons of Asian seabass, 13 tons of cobia and 11 tons of pompano after a period of 6 months culture. Members of each group made a profit of ₹50,000 to 58,000 from the farming operation. Success achieved in the present farming programme encouraged the SHGs to expand cage farming to many more areas along the coast.

Information source utilisation by farmers involved in cage culture of finfishes: a study in coastal Karnataka

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Keywords: Cage culture, Farmers, Information source utilisation, Traditional fisherfolk

Cage aquaculture is gaining prominence as an alternate source of livelihood for the traditional fishermen of coastal Karnataka. The transfer of technology programmes of the Mangalore Research Centre of Central Marine Fisheries Research Institute (CMFRI), has led to the adoption of cage culture of finfishes such as seabass and red snapper in the estuaries located in the backyard of their households on a subsistence scale. It has provided the traditional fishers with an alternate source of income generation during the lean fishing season. The study analyses the information source utilisation behaviour of these fishers since it is an important socio-psychological variable influencing the adoption of cage culture practices. Data was collected using a structured interview schedule. Purposive sampling method was used to collect data from a sample of 47 cage farmers in Dakshina Kannada and Udupi districts. The findings revealed that, the information source utilisation index was highest (295.74) for personal cosmopolite sources (Fisheries scientists and fisheries research institutes) followed by impersonal cosmopolite sources such as demonstrations, meetings and seminars (293.62). Most of the farmers had a medium level of information utilisation behaviour (40.42%) followed by low and high levels (29.79%) respectively. Results of correlation analysis revealed that variables such as age, annual income and innovativeness had a positive and significant association with information seeking behaviour of cage farmers. Educational status had a negative and significant association with information seeking behaviour. The results of multiple regression analysis revealed that variables such as age, educational status, annual income, social participation and innovativeness explained 60.90% of the variation in information seeking behaviour. Analysis of variance for regression revealed that the F value was highly significant ($F=12.78$ at $p<0.001$). The study recommends the need for effective utilisation of impersonal cosmopolite sources such as mass media, print and electronic media to complement the efforts of fisheries scientists and extension agents for widespread adoption and diffusion of the technologies across the social system.

Cage aquaculture: a tool for participatory management of coastal waters and fish stocks

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Keywords: *Cage aquaculture, Coastal ecosystems, Conservation, Participatory management, Sustainability*

Sustainable fishing, conservation of fishery resources and preservation of coastal ecosystems form a complex triad of necessary activities that need to be juxtaposed in the best possible way to provide the ideal formula for fisheries management. India, today faces the threat of increasing fishing pressure, depleting fish stocks and steady degradation of many coastal ecosystems due to a combination of anthropogenic and natural factors. Cage aquaculture presents a solution to these issues as it is a platform widely acceptable to fishing communities and easily adapted by them as an allied or alternate activity. A series of demonstrative and participatory trials on open sea cage farming of different species of fishes and lobsters in coastal villages of Kancheepuram District in Tamil Nadu on the southeast coast of India have clearly indicated that proper integration of scientific approach with the natural know-how of the fisherfolk makes cage aquaculture an efficient tool for sustainable fish production, resource conservation and habitat protection. Hands-on training on cage aquaculture practices (including species selection, seed collection, transportation, nursery rearing, stocking, feeding, cage maintenance, sampling, harvesting and live trade) was imparted to fisherfolk of Kovalam, Chemmencherry, Alambrai, and Cuddalore Chinnakuppam. While the fishing community in Kovalam showed an initial resistance to adapting cage aquaculture, fisherfolk of the other villages were receptive. Successful sea cage farming of Asian seabass in Chemmencherry in 2010 paved the way for popularisation of cage aquaculture in adjacent villages and today, Kovalam has developed into a model village for cage aquaculture practices, with many active fishermen participants. Our observations show that the fishermen involved in these exercises assimilate information on breeding, growth, feeding, density protocols, compatibility, weather associated behavioural adaptations, handling strategies, nursery rearing of the different species, and they evolve indigenous techniques to carry out the cage farming and get improved yields. They are quick to understand even the minor changes in the surroundings, the benthos, the foulers and other live aggregations in the vicinity of the cages. With fishermen spending more effort and time in rearing different species, there is a visible change in their disposition towards the need to revive falling stocks in the coastal waters. Moving from hunter to farmer, they are quick to appreciate the opportunity cage aquaculture offers towards regulating their dependency on wild stocks and of working together towards replenishing the sea instead of only taking from it.

Techno-economic viability of open sea cage farming of cobia *Rachycentron canadum* undertaken by a fishermen self help group

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Keywords: Cage farming, Cobia, *Rachycentron canadum*, SHG

Mariculture of commercially important marine fishes like cobia *Rachycentron canadum*, pompano *Trachinotus blochii* through open sea cage farming has gained momentum in the country due to their fast growth rate, high market demand, availability of stockable size fingerlings, easy farming methods and better economic returns. The techno-economic viability of open sea cage farming of cobia has been successfully demonstrated by the Mandapam Regional Centre of Central Marine Fisheries Research Institute (CMFRI) through public-private partnership (PPP) programmes with fishermen self help groups (SHGs). A fishermen SHG namely, Cobia Fisherman Welfare Association, from Rameswaram took up sea cage farming with technical support of Mandapam Regional Centre of CMFRI. This is the first sea cage farming venture by a fishermen self help group, with all the expenditure being incurred by the group. Galvanized Iron (GI) cages (4 nos.) of 6 m dia and 3.5 m depth fabricated and installed in the Gulf of Mannar were stocked with 6,600 nos. of cobia fingerlings (in the size range of 12.1 - 18.5 cm and 16 - 23.7 g). The initial stocking density was maintained at 18 cobia fingerlings per m³. The fingerlings were fed trash fish *ad libitum* once in a day. When the fishes attained an average size of 150 g they were distributed evenly in a total of 9 cages to maintain 730 nos. of cobia fingerlings per cage, amounting to 8 nos. m⁻³. Farming was initiated during the middle of November 2013. On 8th May 2014, the fishes were harvested. A total of 9 tons of cobia was harvested. The length of harvested fish ranged from 48 to 62 cm, with weight ranging from 1.5 to 2.3 kg. Fishes were sold at a farm gate price of ₹270 - 320 per kg. This was proved to be a successful and profitable venture and considered as a milestone in the development of open sea cage farming in India.

Women empowerment through aquaculture in India: strengths and weaknesses

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Keywords: *Aquaculture, Intergrated cage farming, Mabe pearl farming, Women empowerment*

Aquaculture is one of the major sources of livelihood for coastal villagers and women in the families have taken up responsibilities ranging from seed collection to marketing farmed produce. During the past two to three decades, women from low income group families have been given opportunities to expand their sphere of activities and they have started earning and contributing to family income through their own group or cluster activities. In this phase change from a 'supportive' mode to an independent style of functioning, women have received considerable support from development schemes promoted by banks and developmental agencies.

Experience in developing and transferring mariculture technologies in two mainland states (Kerala and Tamil Nadu) and one island territory (Andaman and Nicobar Islands) have shown that women have the strength to learn new technologies and adopt the same in their villages. The level of technology adoption was highest in Kerala and lowest in Andaman and Nicobar Islands. However, it was observed that in Indian villages, women were found to give priority to their family responsibilities which limited their sphere of activities to areas very close to their household and also limited their time for aquaculture activities. This was found to affect marketing of the farmed produce. In areas where women have expertise in farming, there is an urgent need to link village production units with the right market outlets. It was observed that women need special training in small business management. Even in Kerala, where women literacy rate is high, the commitment to family responsibility, especially those related to upbringing of children reduced the time spent for marketing, affecting growth and expansion of their aquaculture activities. In addition, support from men in the family was found to be low. Considerable motivation and support is required for adopting entirely new technologies like mabe pearl farming and integrated cage farming. The country has very high potential for aquaculture development, and this can be advantageously used for empowering women, but there should be slightly different approach for each type of technology. Exploring the market and selling the product through varied marketing strategies should be a new activity and it is suggested that village or semi-urban youth having wider contacts are motivated to market the farmed produce of women self help groups. Thus aquaculture can become village-semiurban-urban job provider and youth with more communication skills can support women empowerment in villages. The profit earned can be increased substantially through simple management measures, advertisements and development of markets.

Open sea cage culture in India: policy requirements and opportunities

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Keywords: Cage culture, Participatory approach, Technology development

The Indian fisheries sector has undergone a paradigm shift in the last three decades and it contributes to the food security, employment opportunities and export earnings. Amidst reaching a 10 million tons production there exists numerous demand-supply mismatches coupled with technical and institutional constraints. The issues of fish availability, accessibility and affordability resulted in higher prices causing fish food security concerns for the ever growing consumers. The contribution of the marine fisheries sector has been showing a decelerating trend which necessitates the need for harnessing alternative fisheries production system. Open sea cage culture provides an alternative production system with better resource productivity coupled with improved fish production with low gestation period and employment generation across value chains (hatchery, feed, marketing, export) and thereby providing alternative. The Central Marine Fisheries Research Institute (CMFRI) has pioneered open sea cage culture in India and had been instrumental in the horizontal and vertical integration of technology across the country with localizing the technology and demonstration of rearing protocols of several high value finfish and shellfish species like seabass, pompano, cobia and lobsters. The technology adoption is operational under the following phases viz. site selection, location testing, technology demonstration, technology evaluation (output maximization and cost minimization with stakeholder participation), commercialization and development of alternative livelihood.

The paper estimates the incremental fish production in India which could be generated by popularisation of the cage culture across the Indian sea coast supported with flexible policy initiatives from the planners. The study also identifies the different policy lacunae which the sector could pose on account of the multitude of other activities in the coastal waters and its possible tradeoffs, issues of resource ownerships and legal entitlements of cages and its sites, broodstock development and seed production, constraints - technological, infrastructural and institutional, cost effective feed development and social engineering among the primary stakeholders. The study suggests the need for developing participatory approaches. The paper advocates the need for evolving flexible guidelines in providing governmental support for administering cage site selection, leasing, entitlements/ownerships and also in creating infrastructure for seed and feed development for better resources productivity and increasing fish production for the future.

Empowerment of sidi adivasi tribes through sea cage farming technology

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Keywords: *Alternate livelihood, Cage culture, Empowerment, 'Sidi' tribes, Socio-economic development*

The "sidi" adivasi, an exotic primitive tribal group from African-sub continent living in Gujarat who fall under below poverty line (BPL) were selected for the sea cage farming technology transfer and demonstration under the Tribal Sub-Plan (TSP) of the Government of India implemented by the Central Marine Fisheries Research Institute (CMFRI). Majority of the tribals work as labuorers in fishing vessels, agriculture fields and industry, which provides very meager unsustainable income leading to poor livelihood standards. Open sea cage farming technology developed by CMFRI gained importance and is widely spreading across the country in recent years. The farming technology was used as tool to provide livelihood option and upliftment. The sidis are identified as potential target group for the cage culture technology transfer and demonstration.

A pilot scale multi-trophic sea cage farm comprising of 20 galvanized iron (GI) circular 4 m dia cages with HDPE floating barrels was established in the Arabian Sea, along the northwest coast of India, for marine finfish and shellfish farming. Twenty families from a registered tribal society were trained in capacity building on different mariculture practices before implementing the programme. Culture protocols were adopted for high value species viz. spiny lobster *Panulirus polyphagus* and cobia *Rachycentron canadum* in cages. Seventeen cages were stocked with different size groups of natural lobster seeds collected from Mahuva region of Gujarat and two cages were stocked with hatchery produced cobia seeds with an initial stocking size of 60 -100 and 60 g respectively. Trash fish was used as feed @ 10% body weight and tray feeding technique was adapted to the lobsters whereas feed was broadcasted for cobia. Seed collection, transportation, feed procurement, feeding and farm management were done by the group members. The total production of lobsters from each cage was about 150 kg with an average weight of 220 g when harvested after 120 days and crop sold for live export which fetched ₹1200 per kg. Production of cobia on harvest was about 110 kg from each cage with an average weight 1.2 kg and fetched ₹200 per kg. Each family benefited with a sustainable income of ₹1.3 lakhs per crop. It is concluded that the sea cage farming technology can play vital role in reducing poverty and enhancing employment opportunities to the sidi tribes and could also provide potential alternative livelihood option for sustainable income which shall be promoted further.

Cage culture of pearlspot *Etroplus suratensis* for livelihood enhancement of the fisherwomen of central Kerala

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Keywords: Cage culture, *Etroplus suratensis*, Growth, Kerala, Pearlsport

Etroplus suratensis known as pearlspot or green chromide is widely distributed in the fresh and brackishwaters of south India and Sree Lanka. It is a delicious table fish with good flavour and taste. Due to its high market demand, herbivorous feeding habit, non- predatory and hardy nature, has been identified as one of the most suitable candidate fishes for pisciculture. This indigenous fish of Kerala has been declared as signature fish during the year 2010 by the Government of Kerala and concerted efforts are being made to increase its production. With a view to empowering the womenfolk and providing gainful employment, Kerala University of Fisheries and Ocean Studies (KUFOS) made an attempt to standardize the cage culture of *E. suratensis* under the Rashtriya Krishi Vikas Yojana (RKVY) funded project "Sustainable Fisheries Development for Rural empowerment and Food Security in Puthenvelikkara Grama Panchayath, Ernakulam District, Kerala" during 2010-2014 with the involvement of Department of Fisheries, Government of Kerala. Women beneficiary groups consisting ten members each were organized in Puthenvelikkara Grama Panchayath. Young ones of pearlspot (4 cm average size) were stocked in cages (2 x 2 x 2 m) at a stocking density of 80 m⁻³, during the month of October 2014 and fed with floating artificial feed of 35% protein content. After six months growth, the fishes were harvested during the prime season when fishes ranging between 250 to 300 g were obtained. The specimens grew to an average weight of 278 g, with 81% survival and the production was 18 kg m⁻³, The food conversion ratio (FCR) was 1:1.5. An estimated production of 144 kg per cage was realized fetching about ₹64,800 per cage at a selling price of ₹450 per kg. The technology was found to be cost- effective, women-friendly in nature and can be adopted by the SHGs without much difficulty on account of its capital light and technology light nature .

Gender mainstreaming and impact of self help groups on cage farming in Vembanad Lake: a case study

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Keywords: *Empowerment index, Gender mainstreaming, Performance level, Self help group*

Vembanad Lake is conspicuous for the brackishwater cage culture undertaken by the mobilized self help groups (SHGs) of fisherfolk. As much as 27 fishermen mobilized under Vembanad Kayal Samraskhshana Samithy, Srayithodu Unit as SHG accomplished the farming of commercially important fishes in 20 cages in Vembanad Lake with financial assistance from Agency for Development of Aquaculture-Kerala (ADAK) as a part of *Kuttanadu* package. The technical assistance was provided by the experts from Central Marine Fisheries Research Institute (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 Vembanad site and training programmes including cage fabrication and cage installation along with seeding and feeding with video documentation were successfully carried out. The fish species chosen for culture were pearlspot and tilapia, as they are highly adaptable to salinity fluctuations in Vembanad 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 in terms of access to resources, participation profile, decision making aspects and gender need analysis. Though majority of activities are male dominated, the female counterparts of the households also have definite role in decision making, feed preparation, management, harvesting, sales and marketing. The social and economic empowerment dimensions and capacity building aspects achieved highest score in empowerment index. The economic feasibility analysis gave a benefit cost (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 mobilizing SHGs on a sustainable basis.

Community based fish cage culture: an employment generation option for rural youth at Palasawada and Kadavai villages in Maharashtra

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Keywords: All male tilapia, Cage culture, Employment generation, Reservoir, Self help group

“Fingerling Bank” concept initiated by the unemployed rural youth of Therawadi and Kadavai villages in Maharashtra are worth mentioning. This project was funded by the Rajiv Gandhi Science and Technology Commission (RGSTC), Mumbai. In the first phase, beneficiaries were selected from the Therawadi and Kadavai villages and formed a self help group (SHG), and were registered in the office of the Taluka Magistrate. One battery of 4 and 3 cages each (each cage 6 x 4 x 2 m) were fabricated and installed in the Palaswada and Kadavai reservoirs, respectively. Hands-on training on fish cage culture in underutilized water bodies were given to the SHG at project site, covering all aspects of seed stocking, feeding, cleaning of the cages and counting of the seed. Three lots of the Indian major carp, catla and one lot of common carp fry (10Vembanadu15 mm size) were stocked @ 1000 nos. m⁻³ in cages and nursed for two months to attain a size above 80 mm. Survival of 70% was achieved by feeding ground nut oil cake and rice bran (1:1) and mineral mixture (agrainin 2%), three times a day @ 15% of the body weight.

In Palaswada Reservoir, fish fingerlings were sold to 86 farmers having their farm ponds. As on 31st March, 2015, the SHG earned revenue of ₹5.25 lakhs by way of selling 3.5 lakhs fingerlings and an amount of ₹24,000 as monthly savings was deposited in the SBI account. Indirectly, 86 farmers who started rearing fishes in their farm ponds (1200 gunthas) produced around 60 tons of fish. In Kadavai Reservoir, fish fingerling of common carp of >70 mm size were released in the open water of the same reservoir having 14 ha area. Marketable size fishes were harvested and sold in the local market @ ₹200 kg⁻¹. This is the first SHG in the state that ventured in to cage fish culture and marketing.

Adoption of CMFRI technology for sea cage farming: a success story from Ramanathapuram District, Tamil Nadu

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Keywords: Cage farming, Cobia, Demonstration, SHG

Marine fisheries sector in Palk Bay and Gulf of Mannar region is witnessing overexploitation of trawling grounds, declining catches and consequent reduction in profit. Other burning issues of this area are inadvertent crossing of International Maritime Boundary Line (IMBL) by the Indian trawlers and loss of livelihood of fisherfolk due to the biodiversity conservation measures of Gulf of Mannar. In order to address the issue of declining capture fisheries, the major management strategy followed worldwide is the adoption of fishing holidays. Another option is to ban trawling in a phased manner. Alternative options should be provided to these fishermen for the livelihood. Globally, increasing demand for seafood is forcing for additional seafood production through farming of fishes in open sea cages, coastal ponds and pens. The Central Marine Fisheries Research Institute (CMFRI) has developed breeding, seed production and farming technologies for two commercially important high value marine finfishes namely cobia and snubnose pompano. The message about the techno-economic viability of farming of these fishes in sea cages and ponds has reached the fishermen of the area through different training, awareness and frontline/participatory demonstration programmes organised at Mandapam Regional Centre of CMFRI. Realising the profits in sea cage farming, few fishermen self help groups (SHG) started cage farming of cobia with their own financial investment with the technical support of CMFRI during 2013. Their success has motivated many fishermen groups and the district administration to popularize this activity. Ramanathapuram District administration mooted a new scheme under the State Balanced Growth Fund to assist 10 SHGs to take up sea cage farming with 90% subsidy for two cages per group. Apart from these 10 SHGs, five more SHGs have already commenced the farming with their own financial investment. A study was conducted to assess the socio-economic and technological perception about the sea cage farming of cobia from all the fishermen groups presently involved in farming. The innovation or modifications made by the farmers in cage farming were also documented. The study found that the important attributes which attracted the fishermen groups to take up the farming were fast growth rate of cobia, shorter culture period, good farm gate price, high market demand, farming near the seashore, seed availability and technical guidance from CMFRI.

Small scale cage farming initiatives in Karnataka: a case of successful technology adoption leading to rural livelihood transformation

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Keywords: *Cage farming, Finfishes, Karnataka, Livelihood, Small scale*

Karnataka State has 300 km coastline with unpolluted brackishwater area of about 8000 ha. Over the years, a decline in estuarine fish production has occurred and the fishermen depending on estuaries were deprived of their livelihood. To address the livelihood issues, finfish culture of red snapper, seabass and pearlspot in small cages was initiated and cage culture techniques were demonstrated in the saline creeks and estuaries in the year 2009. The demonstration started with 5 cages in 2009 - 10. The grow out was successful and at the end of the culture period of 10 months, about 1.8 tons of fishes were harvested from the cages. The harvest was done during the lean fishing season and it provided an income and alternate livelihood for the fishermen who otherwise depended on estuarine fishing for their living. This encouraged more and more fisher families to come forward for backyard model cage farming and presently 35 cages are installed along the coast. Modifications in cage design and operation were done continuously over the years, which led to an overall increase in production from the cages, from 1.8 tons in 2009 - 10 to 11 tons in 2013 - 14.

The technology was disseminated successfully and it involved technology demonstrations through participatory approaches, focussed group discussions, training by experts, technical assistance in site selection, cage fabrication, management, 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 and empowerment of fisherfolks are the 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. Carangid groups are the latest addition to the list of species cultured successfully in cages. The sustained cage farming initiative and interventions carried out by the Central Marine Fisheries Research Institute (CMFRI) has provided alternate livelihood options and livelihood diversification for coastal fishers. This would also address the nutritional and financial security of the coastal fishers. Present assessment shows that a minimum of 260 cages could be installed without affecting the coastal environment. It would also lead to an increased production of 500 tons of fish every year.

Comparative assessment of conventional and cage fish farming in Ernakulam District, Kerala

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Keywords: Cage culture, Conventional fish culture, Fish production and performance

Marine capture fisheries have almost reached a phase of stagnation and there is limited scope for expansion. The inland capture fisheries sector also faces challenges in which the specific needs are to be addressed. However, its full potential has not been exploited and there exists ample scope for diversification. Aquaculture is one of the fastest growing food production systems and India ranks second in world aquaculture next to China. Cage culture has been practiced since 1950's in Southeast Asian countries like China, Thailand, Cambodia, Philippines and Indonesia. But, it is still in its infancy in India. Kerala is one of the leading states as far as fish production is concerned. Almost 97% of Kerala's fish production comes from marine fisheries and only a small percentage is from inland water bodies. Considering the variety and spread of water bodies in the state, cage culture is an important alternative fish production system that needs to be explored and popularized. There have been attempts in this direction over the last decade. An attempt is made in this paper to assess the performance of cage culture as against conventional fish culture in Ernakulam District of Kerala.

Socio-economic dimensions and SWOT analysis of sea cage farming in Goa

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Keywords: Participatory cage farming, Self help groups, Socio-economics, SWOT analysis

Open sea cage farming is a means for augmenting fish production as well as an alternate livelihood source to the fisherfolk in the context of declining capture fishery resources. Participatory sea cage farming was undertaken by the Department of Fisheries, Goa through the fishermen self help groups (SHGs) under the technical guidance of Central Marine Fisheries Research Institute (CMFRI) and financial assistance from Rashtriya Krishi Vikas Yojana (RKVY) scheme. Seabass, cobia and pompano were the major fish species cultured in the open sea cages in Goa. The SWOT analysis of sea cage farming in Goa was done based on the information collected from beneficiary fishermen SHG members, non-beneficiary fishermen, fisheries department officials and research organizations. SWOT analysis is a planning tool which helps to understand the strength, weaknesses, opportunities and threats of a project or business.

The socio-economic dimensions of the participatory cage farming were also analyzed in Polem, Talpone and Nuvem fishing villages in Goa. The beneficiary fishermen belonged to motorized and non-mechanized categories and were able to generate an average monthly income of ₹6,000 to 10,000 through the fishing operations. The cage farming generated an additional per-capita revenue of ₹35,000 to 50,000 per farming season for the SHG members.

The major strengths of participatory cage farming were effective institutional linkages, technological support and training opportunities, cooperation and teamwork among fishermen and good market demand for the species and the major weaknesses were mortality of fish due to diseases, non-availability of quality seeds, improper stocking time, difficulties with disease management in the open seas and poor entrepreneurial capabilities in the absence of financial support. The opportunities are plenty in the vast stretches of open sea available for culture operations, declining capture fishery yields of small scale fishermen and demand for high value fishes for the tourism sector. The major threats were lack of sea leasing policies, poaching by fishermen from neighboring states, uncertain yields due to climate change and diseases and lack of insurance facilities. The suggested action plan for successful cage farming focus on the need for large scale production of disease free quality seeds through promotion of certified agencies with public-private partnership, development of quality feed, development of sea leasing policies by the government and entrepreneurial capacity building of the fishermen groups.

Cage culture as an option for alternative income and livelihoods: the experience of the traditional aquafarmers of Kerala, India

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Keywords: *Brackishwater, Cage, Chanos chanos, Kerala, Milk fish*

Like in other Asian countries, in India also, coastal aquaculture refers to farming of shrimp for export and is often associated with environmental degradation. Development of aquaculture for rural development is not in practice in many countries including India. This paper shows that cage aquaculture could contribute significantly to the livelihoods of the poor, particularly in the under developed areas of Kerala and as an alternative income for the traditional shrimp farmers, although many constraints prevent its expansion. Recent adoption of this technology suggests that with adequate support, cage culture could contribute significantly to the improvement of the rural livelihood where it is neither a traditional nor widespread practice. In rural Kerala, poor fish farmers do aquaculture as a traditional practice; they sell shrimp/fish to generate income, have knowledge in farming too; while, reluctant to go for new technologies, fearing its implications on their minimal income. Participatory approaches in cage farming have led to the adoption of the technology by new entrants/poor households in Kerala. ICAR - Central Marine Fisheries Research Institute (CMFRI) provided them with training in cage fabrication, mooring, net tying, feeding, grading of fishes, net changing and harvesting. The fishermen group at Parur in Ernakulam District were enthusiastic about the new technology, but were reluctant to do because of their poor financial status. CMFRI has intervened and with a successful demonstration of grey mullet *Mugil cephalus* farming, they have been empowered in doing farming in the next season. The fishermen got additional and better income and are continuing cage farming for the past three years, with their own innovations and multi-species farming. A group of rural fishers at Kaipamangalam, Thrissur District were trained in cage farming and through demonstrations by CMFRI the group got empowered and are doing farming of pearl spot, *Pangasius* and mullets in cages. The experience of progressive traditional shrimp farmers at Kochi is different. They were approaching different agencies for intervention in getting alternative income from their farms other than the regular shrimp sale, which often ends up in huge loss due to diseases. Intervention by CMFRI has resulted in an empowered team of progressive farmers who are earning quite a good income from cage farming for the past three years. The species they farm are GIFT tilapia, Asian seabass, milk fish, pearlspot and grey mullet. The production from a 4 x 4 m cage ranged from 500 to 2000 kg in a culture period of 5 months to one year. An income realization ranging from ₹50,000 to 15,00,000 per cage could be obtained by farmers through cage culture depending on their input levels.

Polyculture of fishes in open water cages: a better option for year round fish production and income

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Keywords: Cage culture, Pearlsplit, Polyculture, Red belly, Tilapia

One enthusiastic engineering graduate (private farmer) from Chengannoor has proved that poly culture of fishes in cages in open water is a means of year round fish production as well as better income. The farmer started cage culture in the open waters of river Pampa with the technical help of Central Marine Fisheries Research Institute (CMFRI) in the year of 2014. Five numbers, of galvanized iron (GI) cages measuring 6 x 6 m size were fabricated using GI pipes and moored in the river. Double mooring was done using concrete blocks at a depth of 5 m. The cages were stocked with seeds of 650 nos. of pearlsplit *Etroplus suratensis*, 1200 nos. of GIFT tilapia, 250 nos. each of catla and rohu, 500 nos. of mrigal and 1000 nos. of red bellies at different times and harvested when they were grown to the market size. The farming was being done by a single family at their own costs. Natural seeds of pearlsplit collected from local and other areas were stocked in the cages. All the fishes have grown very well in the cages without much health or water quality problems. The fishes were fed thrice a day with Godrej floating feeds, cooked rice and wheat at a feeding rate of 10% body weight during the entire culture period while continuous stocking was being carried out. Red bellies which grew faster were harvested and sold in the local markets after a period of 5 months. They attained a size of 380 to 720 g and 15±6 cm with a survival rate of 90% and fetched ₹120 -160 per kg. A total of 580 kg of red bellies were harvested earning an amount of ₹80,000 in 5 months of culture. Among the 1200 nos. of GIFT tilapia stocked, about 90% grew to a size of 600 - 750 g (max. size attained - 900 g) and they were harvested after 7 months, fetching a price of ₹200 to 230 per kg as it was sold during the festival season. A total of 800 kg of fishes were harvested and sold in the local markets and earned around ₹1,50,000 during the month of April. Due to the sudden change in the temperature during the stocking time, survival of pearlsplit was comparatively less and only 40% of the stocked fishes were harvested. The fishes attained a size of around 180 to 250 g and 11±4 cm in 8 - 9 months and fetched a price of ₹600 per kg in the local markets contributing to the income. A total of ₹30,000 was earned through the sale of this species at the end of the culture period. Growth of catla, rohu and mrigal was not encouraging; they grew only to a size of 300 to 400 g with a survival rate of 70% till the end of the culture, which might be due to competition for the food. The total culture duration was 9 - 10 months; with a total production of 1380 kg of fishes. The total revenue earned was about ₹3,00,000 in one year.

Participatory approach for standardising cage culture of giant trevally *Caranx ignobilis* in Thiruthipuram backwaters, Kochi, Kerala

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Keywords: Cage culture , *Caranx ignobilis*, Diversification, Kerala, Trevally

Diversification of aquaculture activities has already been identified as an important avenue for augmenting fish production in order to create employment opportunities for the fisherfolk. It will also contribute towards additional utilization of inland water bodies. Among Indian states, Kerala is especially bestowed with various water resources. In the brackish water sector, more than 77% of the area is still left unused. If planned properly, this can offer great potential for diversification of aquaculture practices by promoting innovative, sustainable, and eco-friendly farming techniques among the community. Cage culture of a variety of fishes occupies a predominant place in the diversification of aquaculture which will play a pivotal role in maximizing fish production from unit area. It has gained momentum in several countries and in the State of Kerala as well. As such, steps are being taken by the Government to promote this technology in suitable water bodies. Under the Rashtriya Krishi Vikas Yojana (RKVY) funded project "Sustainable fisheries development for rural empowerment and food security in Puthenvelikkara Grama Panchayath, Ernakulam District, Kerala," (*Samagramatsyagramam*) during 2010 - 14, Kerala University of Fisheries and Ocean studies (KUFOs) has made an attempt to standardize the cage culture of *Caranx ignobilis* (giant trevally) in Thiruthipuram backwaters of Kochi with the participation of Department of Fisheries, Govt. of Kerala. Young ones of giant trevallies at a size of 5 cm were stocked in cages of size 2 x 2 x 2 m at a stocking density of 80 m⁻³ during the month of October 2014 and fed with small sized low value fishes. The fishes were size graded during the month of January 2015 and the bigger ones were stocked in another cage of same size. After a period of nine months, the average size of the fish was 1.358 kg. The weight of the fishes ranged between 1.25 to 1.55 kg with a survival rate of 78.43%. Food conversion ratio (FCR) was 1:1.6. The production obtained was 44 kg m⁻³ and a total production of 348.37 kg per cage was achieved fetching ₹1,21,929 at a selling price of ₹350 per kg. The technology was found to be cost effective, easy to manage with less capital investment and can be adopted by individuals/farmer groups. It will definitely serve as an alternative way for increasing the inland fish production of the state, contributing to food and nutritional security leading to enhanced employment and income.

Open sea cage culture of pompano *Trachinotus blochii*: an alternative livelihood approach for coastal fishers at Achara, Sindhudurg District, Maharashtra

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Keywords: Cage culture, Growth, Rectangular galvanized iron cage, *Trachinotus blochii*

The dwindling marine fisheries resources and increased fishing pressure leading to low fish catch, necessitated alternate livelihood options for marginal fishers at Achara in Sindhudurg District of Maharashtra. Open sea cage culture of pompano *Trachinotus blochii*, was attempted with a group of young and active fishers off Achara, Sindhudurg District. Two rectangular galvanised iron (GI) cages (5 x 5 m) were installed. The cages were installed at Achara Creek mouth to avoid heavy wave actions. A total of 1342 pompano seeds having average weight of 4.06 ± 0.26 g procured from Mandapam Regional Centre of Central Marine Fisheries Research Institute (CMFRI) were stocked in cages in the month of January 2014. Juveniles were fed four times a day with formulated floating feed (50% crude protein) and trash fish @ 20% of body weight for the first month of rearing. Regular fortnightly sampling schedule was undertaken for monitoring health and growth. Water quality parameters were recorded weekly. Fishes were reared for twelve months period and harvested in February 2015. Survival rate of 58% with final average weight of 308.85 ± 10.46 g was recorded in Cage I whereas in Cage II 62% survival rate with final average weight of 315.90 ± 14.11 g was recorded. Reasons for slow growth and comparatively less survival as compared to the other field trials on cage culture may be due to stress due to stormy weather conditions in the region. Paper elaborates future options of new resource utilization with emphasis on alternative livelihood for coastal fishers.

Participatory trial on pen farming of milk fish *Chanos chanos* in Pillaimadam Lagoon of Palk Bay, Tamil Nadu

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Keywords: *Chanos chanos*, Milk fish, Pen farming, Palk Bay, SHG,

Capture based aquaculture (CBA) is a type of aquaculture where in regular stocking of fishes is carried out with wild caught juveniles in pens and ponds. Such juvenile fishes grown in enclosed areas with supplementary feeding would reach marketable size with good survival rate. A trial on pen farming of milk fish *Chanos chanos* was initiated in a participatory mode with a fishermen group of Vedalai Village, Ramanathapuram District during the month of May 2014. The fishermen Self Help Group (SHG) erected an artisanal pen with dimension of 120×120 m supported by casuarina poles in the Pillaimadam Lagoon of the Palk Bay. About 25,000 milkfish *Chanos chanos* seeds collected from the lagoon with average length and weight of 6.3 cm and 4.6 g were introduced. All investments towards the cost of fish nets, casuarina poles and labour were borne by the group. Supplementary feeding with extruded floating pellet feed containing 24% crude protein and 4% fat @ 1% of the biomass was given. Mandapam Regional Centre of Central Marine Fisheries Research Institute (CMFRI) extended the technical support for farming, water quality and growth monitoring. Four feeding zones were erected using PVC frames. After a rearing period of 10 months, a total of 2,562 kg of milk fish was harvested with an average length and weight of 33 cm and 300 g respectively. The fishes were immediately sold at nearby fish market at ₹140 per kg. This has given confidence to the fishermen SHG that the pen farming of milk fish can be taken up by adopting scientific methods for increased profit.

Participatory demonstration of sea cage farming of spiny lobster at Thirumullavaram, Kollam, Kerala

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Keywords: Cage farming, *Panulirus homarus*, Spiny lobster, Submersible cage

Spiny lobsters are available from Kollam to Kanyakumari during almost all months except the peak monsoon season. Lobsters are mainly caught and marketed in live condition. There is no selective harvesting and most often juveniles are being caught during the operations. Vizhinjam Research Centre (VRC) of CMFRI has carried out successful demonstration of sea cage farming of lobsters and seabass in floating cages at Vizhinjam, Muttom and Chinnamuttam areas. Nearshore areas of Thirumullavaram (Kollam District) are natural habitats of the spiny lobster *Panulirus homarus*. These areas are shallow with rocky formation of laterite stones having many small rock pools which are ideal for small submersible type of cages.

The VRC of CMFRI conducted a small lobster farming trial in order to create awareness and interest among fishermen groups of Thirumullavaram. A group of four fishermen families staying near to seashore and engaged in lobster fishing were selected after a brief survey at Sarpakkuzhy area near to Thirumullavaram. Farmers were given a short training on different aspects of small scale lobster farming. Whole family including children, women and elders were also given proper awareness about the activities. In a participatory demonstration mode, a 2 x 1 m submersible cage was fabricated with galvanized iron (GI) mesh and frames coated with synthetic resins and fibre paints to reduce rusting and fouling. An inner HDPE cage net was also used for additional protection. This trial was conducted in a participatory mode. Since the site selected was visible from the participant's home, there was no threat of poaching during the demonstration period. Small lobsters (*Panulirus homarus*) collected locally and stocked in the cage with a stocking density of 100 nos. m⁻³. The lobsters were fed daily once using low value fishes collected by fishermen from the same area using gillnets and traps. Average weight at the time of stocking was 72.4 g which grew to 198.4 g in seven months period. Survival was 70.5%, growth rate estimated was 0.67g day⁻¹ and a total of 28.5 kg were harvested.

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