Course Manual

NATIONAL TRAINING ON CAGE CULTURE OF SEABASS

भाकृ अनुप
ICAR

14 - 23 December 2009

कडलमीन
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Central Marine Fisheries Research Institute
(Indian Council of Agricultural Research)
Post Box 1603, Ernakulam North P.O., Kochi - 682 018, Kerala, India

and

National Fisheries Development Board
Ministry of Agriculture, Government of India
Blocks 401-402, Maitri Vihar, HUDA Commercial Complex
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Course Manual
National Training on
Cage Culture of Seabass

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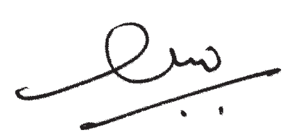
FOREWORD

The culture of aquatic organisms in confined enclosures or "cage aquaculture" has grown tremendously during the past 25 years all over the world. Cage culture is presently undergoing great innovations in response to globalization and the growing demand for aquatic products. It has been predicted that the fish consumption in developing and developed nations will increase by 57 percent and 4 percent, respectively over the coming 10 years. Population growth, increased level of affluence and fast urbanization in developing countries are leading to major changes in supply and demand for animal protein, from both livestock and fish.

In India it has become imperative to identify new and suitable sites for aquaculture and ocean is the limit. Cage culture is accessing and expanding into new untapped open-water culture areas such as lakes, reservoirs, rivers and coastal brackish and marine inshore and offshore waters. Moreover, there is a growing awareness that the possibilities offered by cage aquaculture have only begun to be explored in India. Cage culture offers not only production of food fish, but also it forms an alternative to conventional land based hatcheries, nurseries and even for rearing broodstock fishes in a more natural environment. It can also be employed for rearing of oceanic fishes like tuna and the most sought after crustaceans like lobsters.

Within the Fisheries Division of the Indian Council of Agricultural Research (ICAR), the Central Marine Fisheries Research Institute (CMFRI), Kochi, is responsible for all programmes related to development of mariculture. CMFRI has initiated many successful mariculture activities including breeding and culture of edible oysters, pearl oysters, mussels, marine ornamental fishes, sea cucumbers, *etc.* At present as another feather in its cap, CMFRI has pioneered in introducing successful open sea cage culture of Asian seabass and lobsters at different locations in India. Keeping this in focus, the Institute has organized this National Training for the benefit of the farmers, researchers and extension officers representing all the maritime states in India, with a view to disseminate and share the information and experience in this emerging field of mariculture, in order to enhance their competency and confidence in the area.

I am grateful to National Fisheries Development Board (NFDB), Hyderabad, for sponsoring the programme. I express my gratitude to Dr. (Mrs.) Imelda Joseph, Course Coordinator and other committee members for organizing the programme in a befitting manner. I thank all the faculty members from CMFRI and other organizations like CIBA, CIFT and MPEDA. I take this opportunity to place on record my sincere appreciation for the whole-hearted cooperation extended by the administrative, technical and auxilliary staff of the Institute who have also contributed towards the organization of the training. I am confident that the participants would greatly benefit from this training.



14th December 2009

Dr. G. Syda Rao
Director

PREFACE

Aquaculture aims at producing aquatic organisms of nutritional, ornamental, therapeutic and industrial value. Cage culture is one avenue where immense scope is there for all these. Cage culture is impressive to adopt in the fact that it provides ownership in public water with less cost of construction and reduced capital investment, safety from predators and competitors and ultimately high yield of fish with good economic returns.

The manual being released on this occasion contains the lecture notes presented by the faculty. On this occasion I have great pleasure to record my whole-hearted appreciation to all my committee members for their sincere and dedicated work. Dr. G. Syda Rao, Director, CMFRI, has extended all the possible cooperation and guidance in organizing the Training Programme for which I am grateful to him. I am grateful to Dr. Shoji Joseph and Dr. Boby Ignatius, Senior Scientists, Mariculture Division, for their continued support in looking after the various academic and other field programmes. My thanks are due to Dr. A. P. Lipton, Principal Scientist, Vizhinjam RC of CMFRI, for making the arrangements for the field visit to cages in Kanyakumari district. I am grateful to Shri K. M. Venugopalan, Technical Staff, Marine Hatchery, for assisting in the field work as well as in the conduct of the training programme. I have great pleasure to extend my thanks to Mrs. Susmitha, V., Tijo Varghese and Anu Mathew, Senior Research Fellows, for their sincere and devoted assistance in the various facets of organizing the training. The field support by Shri M. D. Suresh and Shri T. V. Shaji, Skilled Supporting Staff, cannot be ignored on this occasion.

My thanks are also due to all the faculty members and invited speakers. I also express my sense of gratitude to the HRD Cell, CMFRI, for their support in the conduct of the training. I place on record my sincere thanks to National Fisheries Development Board (NFDB), Hyderabad, for sponsoring the training programme.

I am grateful to Mr. Edwin Joseph, Librarian, CMFRI, for his dedicated contribution for the lay out and printing of this manual in time.

I thank Dr. G. Gopakumar, Head, Mariculture Division, for being a motivation in conduct of this training, Dr. Grace Mathew, Head in Charge FEM Division, for her support, other Heads of Divisions at CMFRI, Scientist colleagues and friends. My sincere thanks are also due to the administrative and auxilliary staff and research scholars, who have extended their help.

I am sure that the manual released on this occasion would enable the participants to enhance their knowledge and competence in the field of Cage culture.

14th December 2009

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Overview on mariculture and the opportunities and challenges of cage culture in India

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India is the fourth largest producer of fish in the world and the total fish production is around 6 Mt per year and its share in the GDP is around 1.4%. The world annual growth rate in aquaculture production has been 7.05% since 1971 (FAO 2008). In 2006, aquaculture comprised 41.8% of total seafood supply. Indian aquaculture has demonstrated a six and half fold growth over the last two decades, with freshwater aquaculture contributing over 95 percent of the total aquaculture production. Given the status of global fisheries, with most large fish stocks being fully exploited or over-exploited, aquaculture production must increase in order to maintain or increase the global seafood supply per capita. Fortunately, the aquaculture sector seems well positioned to succeed in this respect. By obtaining control over the production process and closing the production cycle for an increasing number of species, research and innovation similar to what has taken place in agriculture is rapidly improving the competitiveness of aquaculture, and the blue revolution is following the green revolution.

India utilises only about 40 percent of the available 2.36 million hectares of ponds and tanks for freshwater aquaculture and 13 percent of a total potential brackishwater resource of 1.2 million hectares; in other words, there is room for both horizontal and vertical expansion of these sectors. With over 8000 km of coastline there is immense potential for the development of mariculture which has taken roots only in recent years.

CMFRI has developed several mariculture technologies during last 25 years and concentrated mainly on non finfish like green mussel, edible oyster clams pearl oysters sea cucumbers, several species of ornamental fish, as the scarcity or need for edible marine fish culture was not felt. The demand for cultured marine fish is of recent development in India.

CMFRI initiated a pearl culture program in 1972 and successfully developed the technology for pearl production in Indian pearl oysters. Success in controlled breeding and spat production of the Japanese pearl oyster (*Pinctada fucata*) in 1981 and the blacklip pearl oyster (*P. margaritifera*) in 1984 was another important breakthrough. CMFRI also took the lead in the development of the technology required for edible oyster farming during the 1970s. Intensive research on various aspects of the culture of the Indian backwater oyster (*Crassostrea madrasensis*) has been made and the technology has also been developed for the hatchery production of seed.

In India, two species of marine mussels namely the green mussel (*Perna viridis*) and the Indian brown mussel (*P.*

indica) are found in rocky coastal areas. Investigation of the culture possibilities for mussels was initiated in early 1970s by CMFRI which resulted in the development of a range of practices for the culture of these species. Among maritime States, Kerala was the first to recognise the advantages of utilizing mussel farming technology in rural development, from a meagre production in 1997 cultured mussel production rose to 1250 tonnes in 2002 with over 250 mussel farms being established in the estuaries of Kerala.

Considering the substantial contribution aquaculture makes towards socio-economic development in terms of income and employment through the use of unutilised and underutilised resources in several regions of the country, environmentally friendly aquaculture has been accepted as a vehicle for rural development, food and nutritional security for the rural masses. It also has immense potential as a foreign exchange earner.

Aquaculture- a challenging task

Aquaculture ranks among the most risky businesses to enter as an entrepreneur, farmer, or investor. The risk begins with the production process, as farms face several substantial biophysical uncertainties related to disease, water environment, environmental, and climatic conditions. For many species a long production cycle from fingerlings to harvest contributes to the production risk. Market prices for most aquaculture species exhibit significant volatility; market access is often restricted by changing trade regulations; and new competitors continuously enter the market. There are many causes of market risk. Obvious sources are shifts in total supply from farmers and consumer demand that is not fully anticipated when production decisions are made. When aquaculture products are marketed in the international arena, which is the case for most aquaculture species, producers face risks related to exchange rate, antidumping, sanitary and veterinary regulatory changes, and other trade barriers. Finally, aquaculture products are increasingly marketed through large retail chains, where there are risks related to retailers' bargaining power and extensive requirements to suppliers in terms of deliveries (volume, timing,), documentation, certification, Despite high economic risks, the global aquaculture industry continues to attract new production capacity, new entrepreneurs, and new investors. This is a clear sign of the profitability of the industry, as high returns are the market's signal to attract more investors and to increase production. There are two main explanations for this development. The first is a strong underlying growth in the global demand for seafood. This primarily benefits aquaculture as fisheries production cannot grow much above current levels. As an increasing number of the world's people, particularly in Asia, climb from poverty to the middle class, further growth driven by the demand for variety in protein intake and health concerns is expected. The second is rapid development in the technologies on which aquaculture depend, leading to an almost continuous increase in productivity and quality over time. There is still much room for improvement, *e.g.*, in genetic material, feed formulations, disease-control, logistics, distribution, and marketing. With large differences in technological sophistication between different species and regions, one can expect productivity development in aquaculture to continue to improve the competitiveness of aquaculture species, and with increased demand the production will be profitable. However, as new technologies are adopted, the cyclical and risky nature of the industry will also continue.

Cage culture

The cage culture which initiated in Norway during 70s got developed into a high tech industry in many countries all over the world for high value fishes. The major advantage in countries where cage culture has been commercialised is that they have large, calm and protected bays to accommodate the cages safely against any unfavourable weather conditions. But in India, such areas are very few and the sea conditions are unpredictable during monsoon seasons leaving the safety of structures uncertain. Also, the Government of India or any maritime States have no policies regarding commercial mariculture and leave alone open sea cage farming. Many countries try to venture into Indian arena to sell aquaculture equipments including cage related products which are suitable for their environment and may not be to Indian conditions. But, all are reluctant to transfer technologies suitable to Indian conditions and foreign consultants charge exorbitantly for consultancy. Fish farming in cages is a lucrative business for otherwise poor coastal communities and it is an industry that is growing rapidly in many Asian countries. In some countries and locations, cage farming provides an important source of fish production and income for farmers, other industry stakeholders and investors. Of the estimated one million tonnes of marine fish cultured in Asia, probably 80-90 % is from cage farming. Most of the research relates to cage aquaculture in temperate waters, an industry that has been well established for more than 30 years, particularly for salmon. In modern times, cage culture is also seen as an alternate livelihood, for example, for persons displaced by the construction of reservoirs or acquisition of land for other developmental activities. In such a situation, cage aquaculture has emerged as a promising venture and offers the farmer a chance for optimal utilization of the existing water resources which in most cases have only limited use for other purposes.

Cage is an aquaculture production system made of a floating frame, net materials and mooring system (with synthetic mooring rope, buoy, and anchor) as a round or square shape floating net pen to hold and culture large number of fishes and can be installed in reservoir, river, lake or sea. The design of the cage and its accessories can be tailor-made in accordance to the individual farmer's requirements. HDPE float frames installed in open unprotected water can withstand wave conditions. Round cage (volume depends on diameter) with floatation system made of butt-welded HDPE pipes, designed for the culture of fishes such as milkfish, mullet, cobia or pompano seabass, koth, ghol lobsters are used in many countries.

By integrating the cage culture system into the marine aquatic ecosystem, the carrying capacity per unit area is optimized because the free flow of current brings in instantaneous exchange of water and removes metabolic waste and excess feed. Thus economically speaking, cage culture is a low impact farming practice with high economic returns and with least carbon emission activity. In view of the high production attainable in cage culture system and the presence of large sheltered coastal waters in many countries, marine cage farming can play a significant role in increasing fish production.

Success of open sea cage farming in India

For the first time in India a marine cage was successfully launched at Visakhapatnam, in the east coast of India by CMFRI in 2007. The indigenously designed and fabricated HDPE cage was provided with a cat walk for free working on board and stabilization. The cage net was 15 m diameter and 6 m deep. An outer HDPE predator net protected the cage net from damage by large predators. On top of the cage railing, a bird net was provided to prevent bird attacks. The entire structure was kept in position by ballast and ropes tied to the mooring chains. The cage was provided with a shock absorber on the mooring chain to withstand and absorb the pressure of winds, currents and was moored at a depth of 11 m about 300 m from the shore line. The total net volume was 850 cubic meters. This area being under the influence of high water currents, strong waves, and winds and generally rough, the cage was intact. Limited number of Asian seabass, *Lates calcarifer,* was stocked during the first trial and successful harvesting was carried out after four months during the trawl ban period in the east coast. The economic analyses of the operation have revealed the viability of cage culture in Indian waters. Other successful models are lobster

(*Panulirus homarus*) at Trivandrum, Kerala and seabass at Balasore, Orissa. At Balasore, culture of seabass in cage was undertaken during 2009 and despite of several odds, a catch of 3.1 t was harvested with the active cooperation of fishermen.

Opportunities for cage culture in India

General

The Indian sub continent presents open sea aquaculture producers with a number of opportunities:

A huge area to convert to mariculture farm: The Indian coastline is extending up to 8129 kilometres and has a continental shelf area of 5.3 lakh km^2. With numerous creeks and saline water areas the opportunities for cage culture are tremendous in India.

Well experienced fishermen work force: India has a huge human resource of about 14.66 million fishermen population including adult fishermen (8.7 million), full time (0.93 million), part time (1.07 million),and those who are involved in ancillary activities like net making, processing and fish vending (3.96 million). Development of mariculture through cage farming can be taken up with a focus on sustainability through empowering the fishermen by achieving employment generation, social security and increased food security and augmenting sea food exports. Many of these wild fish harvesters represent a highly trained workforce that have extensive knowledge of the ocean, boat handling, net mending and maintenance, fish harvesting and quality control that aquaculture companies can easily adapt to their own operations. In these cases, previous wild fish harvesters would require only some basic training associated with standard farm operations and fish health management.

Strong domestic and export markets: It is a major advantage of Indian sub-continent that it has an excellent domestic market for fish and if supply is assured during fishing ban seasons, the returns to the farmer will be very attractive. Similarly export also can be enhanced for fish if adequate post harvest measures are adopted for live fish export to countries where such fish fetch good market price. At present only shellfish is leading Indian export and the scenario can be changed if we can assure post production quality for harvested marine fishes.

An educated workforce and people with excellent animal husbandry skills: sufficient number of fisheries graduates and specialists in different areas of fish farming (Nutrition, pathology, environment) are available in India to make the cage farming sector technically fool proof.

Local availability of trash fish: There are 3827 fishing villages and 1914 traditional fish landing centers in India and if proper effort is put in preserving the trash fish, they can be utilised for feed, feed ingredient for compounded feed. Availability of local feed manufacturers and suppliers also are added advantage.

Strong research and extension capabilities: In India there are 8 National Fisheries Research Institutes, equipped with well experienced researchers and infrastructure facilities. CMFRI and CIBA are doing extensive research in marine and brackishwater aquaculture and since CMFRI has pioneered in open sea cage farming, it will be an added strength for entrepreneurs to have consultants within the country rather than spending on foreign experts. There are extension researchers as well as officers in different national and state level organisations and it is also helpful when new and novel technologies are introduced to aquaculture sector.

Marine cage culture also presents an excellent opportunity to maintain coastal communities that are presently reliant upon over-harvested commercial fisheries (In the simplest terms one 6 m diameter cage is equivalent to one ha pond on land with regard to production and with less work).

Challenges or constraints

Lack of clear regulations for use of open sea waters: The Indian seas are open to all Indians and the lack of any policy in utilisation of open waters has to be tackled in a positive manner. By allocating areas for cage farming, by means amicable to fishermen and other users of the sea (navigation, tourism) this can be overcome.

Competition arises from other uses of coastal and offshore waters such as recreational boating, commercial fishing and shipping

Rising costs of inputs such as energy and feed: Demand and supply are not matching in many cases and therefore cost escalation in aquaculture operations also inevitable.

Concerns by fishermen about competition from aquaculture: due to lack of awareness and insecure feeling, fishermen resist on any venture in the sea. Only solution is to get them involved in cage culture operations also. By experience in the field they will also change their mind set.

Concerns about environmental effects of aquaculture: Before starting any new venture, it is of no concern about environment or sustainability. But over the years, that becomes the major concern. So before initiating cage culture, it is better to plan out a scheme for environmental concern over the years which will help in flourishing aquaculture rather than killing it.

Technological challenges: Since the industry is new to India, many stake holders will come with many offers, but no proven technology is available so far.

Other challenges

Site selection

Site selection is the biggest challenge in determining commercial viability of cage culture. Identifying a location that has the optimum water quality (temperature, oxygen, light and nutrient levels), current movements and other infrastructure facilities is the most critical factor in cage culture.

Criteria to be considered before selecting a site for cage culture are:

- Site should be at least 6- 8m (depending on the net depth) deep over a sizable area, with sandy or rocky bottom
- Site must have good water quality and should be located away from sources of pollution
- Wind and wave action should be at moderate levels
- Site should not be a regular fishing ground or a navigation channel so that interference would be hindrance for the operation
- Site should have an all weather access
- Nearest beach should have required low valued fish source to be used as feed
- There should be adequate availability of labour and materials
- Cages should be easily monitorable

Cage models

Another challenge to tackle over is in selection of cage models and the design of the cage is directly related to the chosen site, inshore or offshore. According to the analysis of Loverich and Gace (1997) on the effect of currents and waves on several classes of cages for offshore, the most suitable cage is a self-supporting cage. However, for inshore or sheltered sites the conditions change and gravity cages can be used. Some countries tend to move the cages offshore due to legal and possible pollution problems, but the open sea cages face other problem like rough sea. In all the cases, whether inshore, offshore, or sheltered, the cage structures must withstand the forces of the currents, waves and winds, while holding the stock securely. There are a number of types of cages. Beveridge (1996) proposed four basic types: a) fixed; b) floating; c) submersible; d) submerged.

Various cage types and systems are being used for finfish farms all over the world, the choice of which is usually determined by the following main factors:

Site: The most important aspect to be considered is the site in which the cages will be set up and their suitability with regard to (i) exposure to potential sea storms, (ii) seabed characteristics and depth, (iii) prevailing sea conditions, and (iv) visual impact. An exposed site and an increased risk of heavy storms will require cages, nets and mooring systems designed to resist the maximum registered storm strength. If the site is somewhat sheltered, a simplified mooring system and lighter rearing structure will reduce the cost of the initial investment. Should negative interactions be encountered with coastal tourism; submerged or low visual impact models are often considered and/or possibly recommended by the authorities responsible for the issuance of the farming license.

Cost of cages: The initial cost of the investment usually represents a limiting factor particularly for those investors with a fixed budget. However, the cheapest option may not take into consideration the suitability of the structures for the site.

Production plans: The size of the farm and cage model may vary depending on the target pursued by the investors. For instance, farmers aiming to produce a niche product, or attempting to diversify production with fish of various sizes, may prefer a large number of small cages rather than a few large ones so that only a reduced percentage of volume can be engaged in a selected production.

Species selection and seed availability

It is well known that availability of seed in adequate quantities is one of the major challenges in the development and expansion of mariculture. Though seed production technologies have been developed for many marine finfish and shellfish species, many of these technologies have not been scaled up to commercially viable levels. The hatchery seed production of many high value marine finfishes and shellfishes is complex and expensive due to the high costs involved in the establishment of broodstock and hatchery facilities and also to the complicated larviculture procedures involving culture of proper live feeds, their nutritional enrichment, feeding protocols, grading, water quality maintenance, nursery rearing and disease management. The production of seed of the concerned species by development of commercially viable technologies is essential for development of sustainable mariculture practices, but many of these technologies are still in the emerging state and may take several years for standardisation on a cost effective level. High value species like Asian sea bass for which hatchery seed as well as natural fingerlings available at different locations in India is ideal to be stocked in cages. More hatcheries are to be set up for seabass along the Indian coast for continuous supply of seed.

Capture based aquaculture (CBA) is an alternative for those species for which hatchery technology is not developed. As hatchery technologies remain to be perfected for many species, fish farmers have to depend on 'seed' available from the wild. CBA has developed due to the market demand for some high value species whose life cycles cannot currently be closed on a commercial scale. CBA is a world-wide aquaculture practice and has specific and peculiar characteristics for culture, depending on areas and species. The species/ groups that can be harvested as wild juveniles include shrimps, milkfish, seabass, mullets, pomfrets, groupers, red snappers, koth, lobsters It is generally considered that further development of marine aquaculture is possible only by the increase in mass production of juveniles in hatcheries. But it remains a fact that much of world's coastal aquaculture can still be expected to come only from the supply and availability of capture-based juveniles. The species include seer fish, pomfrets, mackerel, koth, shrimps Also, there exists a good fishery for live juveniles of different species of lobsters but very little are used for fattening. It is estimated conservatively that about one million of seer fish juveniles of 7-10 cm and two millions of mackerel juveniles of 5-8 cm land by shore seines in the month of April alone along the stretch of Visakhapatanam- Kalingapatnam. If only a small fraction of these seed/juveniles are induced to be brought in live condition, they form very good source of CBA without affecting the ecosystem and livelihood of fishermen. It will be more lucrative for the fishermen at the same time contributing to several fold increase in the mariculture production. Juvenile yellow fin tuna are available in plenty in and around Lakshadweep waters which can be used for farming in cages.

Feed

Availability of cost effective and nutritionally balanced feed is another constraint for high value fish culture in cages. As on today there is no indigenous scientifically developed marine finfish feed. The development of feed is also very complicated and need to look into nutritional balance for carnivorous fish, feed conversion and cost effectiveness. The imported feeds for seabass are sold at Rs 80/kg which is not economical for most of the farming operations.

Conclusion

With all the challenges to be faced, it is felt that with innovations in cage culture as suitable to Indian conditions can result in opening up a new horizon in Indian fisheries, especially in mariculture.

History of cage culture, cage culture operations, advantages and disadvantages of cages and current global status of cage farming

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Introduction

The earliest record of cage culture practices dates back to the late 1800 in Southeast Asia, particularly in the freshwater lakes and river systems of Kampuchea. Marine fish farming in cages traces its beginning to the 1950s in Japan where fish farming research at the Fisheries Laboratory of the Kinki University led to the commercial culture of yellow tail *Seriola quinqueradiata* and developed into a significant industry as early as 1960. Since the 1970, Thailand has developed cage culture techniques for two important marine finfish: the sea bream (*Pagrus major*) and grouper (*Epinephelus* spp.). Large scale cage farming of groupers were established in Malaysia in 1980. Korea started cage culture in the late 1970s and by the end of 1980, cage culture of the olive flounder (*Paralichthys olivacens*) and black rockfish (*Sebastes schlegeli*) was established, and developed into a successful aquaculture industry in the 1990s. Cage culture of groupers (*Epinephelus* spp.) in the Philippines has been practiced since 1980s. Mariculture of milkfish in the 1990s led to the further growth and development of the industry.

In Europe, cage culture of rainbow trout (*Oncorhynchus mykiss*) in freshwater began in the late 1950s and in Norway, Atlantic salmon (*Salmo salar*) followed in the 1960s. More than 40% of its rainbow trout comes from freshwater cages. Salmonid culture is currently dominated by production from Norway, Scotland and Chile. Cage culture of fish was adopted in USA in 1964.

Currently many fish species have been cultivated in various designs and sizes of cages in Asia, Europe and other parts of the world. Tilapia and carp predominate in freshwater cage culture in Asia, while salmonids are commonly farmed in Europe and the Americas.

The rapid growth of the industry in most countries may be attributed to the availability of suitable offshore sites for cage culture, well established breeding techniques that yield a sufficient quantity of various marine and freshwater fish juveniles, availability of supporting industries such as feed, net manufactures, fish processors *etc.*, strong research and development initiatives from institutions, governments and universities and the private sector ensuring refinement and improvement of techniques/ culture systems, thereby further development of the industry.

Cage culture operations

Cage culture operation involves:

Stocking: The stocking density of fish depends on the carrying capacity of the cages and feeding habits of the cultured species. For those species which are low in the food chain, stocking will also depend on the primary and secondary productivity of the sites. The optimal stocking density varies with species and size of fish and ensures optimum yield and low disease prevalence.

Feeding: Many biological, climatic, environmental and economic factors affect feeding of fish in the cages. Growth rate is affected by feeding intensity and feeding time. Each species varies in maximum food intake, feeding frequency, digestibility and conversion efficiency. These in turn affect the net yield, survival rates, size of fish and overall production form the cage. Trash fish is the main feed for yellowtail, grouper, bream, snapper and other carnivorous fish species cultured in marine cages. The shortage of trash fish is a major problem in many countries with large scale cage farming.

Farm management: Farm management must optimize production at minimum cost. Efficient management depends heavily on the competence and efficiency of the farm operator with regard to feeding, stocking, minimizing loss due to diseases and predators, monitoring environmental parameters and maintaining efficiency in technical facilities. Maintenance works are also very vital in cage culture.

Advantages and disadvantages of cages compared to land based structures

The advantages and disadvantages of cage culture is adjudged by its comparative performance with other land based culture systems in terms of level of technology required for construction, ease of management, adaptability, quality of the fish reared, resource use, social implications, and economic performance.

Advantages

- Construction of cage is comparatively easy, be it artisanal type or modern sophisticated ones.
- Observation of the stock is easy in cages, therefore feeding and routine management is easy
- Cage reared fish are superior in quality in terms of condition factor, appearance and taste
- Cages make use of existing water bodies and thus it can be given to non-land owned people of the community (fishermen) whose income is affected by many reasons in fishing sector. It therefore acts as an alternative income for such groups.
- Harvesting is typically less labour intensive in cages
- Fish are protected from predators and competitors

Disadvantages

- Pond fish can make use of naturally occurring food, while cage grown fish only have a limited access natural food since they cannot forage on their own. Cage grown fish therefore needs to be fed by the farmer to a much higher extent. The food that is given to the cage grown fish also has to be nutritionally complete, *e.g.* contain proper amounts of all necessary vitamins and minerals.

- When fish grown in cages instead of ponds, most farmers opt for a high stocking density. A high stocking density creates a stressful environment for the fish and stress damages the immune system. The risk of disease is therefore high. The risks will be increased further if the farmer fails to provide the fish with optimal water conditions and a satisfactory diet. Cage culture can introduce or disrupt disease and parasite cycles, change the aquatic flora and fauna and alter the behaviour and distribution of local fauna.

- If proper water exchange is not there, the uneaten feed and metabolic waste released from cages will lead to eutrophication of the site.

- Predators can be attracted to the cages and for that additional protection has to be provided such as predator nets

- Poaching is easy because fish are confined in a small area

- Marine cages face problems like fouling and is more expensive

- Storms can damage the cages.

- When cages are installed indiscriminately, its impact on environment and biodiversity is adverse and it will have influence on current flow and increase local sedimentation

- Since cages occupy open water sources, it may affect navigation in the area, or reduce landscape value of that area and are vulnerable to pollution from any source.

Current global status of sea cage farming

Although no official statistical information exists concerning the total global production of farmed aquatic species within cage culture systems or concerning the overall growth of the sector, there is some information on the number of cage rearing units and production statistics being reported to FAO by some member countries. In total, 62 countries provided data on cage aquaculture for the year 2005.

The cage aquaculture sector has grown very rapidly during the past 20 years and is presently undergoing rapid changes in response to pressures from globalization and growing demand for aquatic products. Fish consumption in developing countries will increase by 57 percent from 62.7 million metric tons in 1997 to 98.6 million in 2020. By comparison, fish consumption in developed countries will increase by only about 4 percent, from 28.1 million metric tons in 1997 to 29.2 million in 2020. Rapid population growth, increasing affluence and urbanization in developing countries are leading to major changes in supply and demand for animal protein from both livestock and fish.

The move within aquaculture toward the development and use of intensive cage farming systems was driven by a combination of factors, including the increasing competition faced by the sector for available resources, the need for economies of scale and the drive for increased productivity per unit area. Particularly the need for suitable sites resulted in the sector accessing and expanding into new untapped open water culture areas such as lakes, reservoirs, rivers and coastal brackish and marine offshore waters.

Production

Total reported cage aquaculture production from 62 countries and provinces/regions from where data is available amounted to 2412167 tonnes (excluding China) On the basis of the reported information, the major cage culture producers in 2005 included - Norway (652306 tonnes), Chile (588 060 tonnes), Japan (272 821 tonnes), United Kingdom (135 253 tonnes), Vietnam (126 000 tonnes), Greece (76 577 tonnes), Turkey (78 924 tonnes), and the Philippines (66 249 tonnes).

Major cultured species, cage culture systems and culture environments

To date commercial cage culture has been mainly restricted to the culture of higher value (in marketing terms) compound-feed-fed finfish species, including salmon (Atlantic salmon, coho salmon and Chinook salmon), most major marine and freshwater carnivorous fish species (including Japanese amberjack, red sea bream, yellow croaker, European seabass, gilthead sea bream, cobia, sea raised rainbow trout, Mandarin fish, snakehead) and an ever increasing proportion of omnivorous freshwater fish species (including Chinese carps, tilapia, *Colossoma* and catfish). However, cage culture systems employed by farmers are currently as diverse as the number of species currently being raised, varying from traditional family –owned and operated cage farming operations (typical of most Asian countries; to commercial cages used in Europe and the America).

In terms of diversity, altogether an estimated 40 families of fish are cultured in cages, but only five families (Salmonidae, Sparidae, Carangidae, Pangasiidae and Cichlidae) make up 90 percent of the total production ad one family (Salmonidae is responsible for 66 percent of the total production. At the species level, there are around 80 species presently cultured in cages. Of those, one species (*Salmo salar*) accounts for about half (51 percent) of all cage culture production and another four species (*Oncorhynchus mykiss, Seriola quinqueradiata, Pangasius spp* and *Onchorhynchus kisutch)* account for about another one fourth (27 percent). Ninety percent of total production is from only eight species (in addition to the ones mentioned above: *Oreochromis niloticus, Sparus aurata, Pagrus auratus* and *Dicentrarchus labrax*) the remaining 10 percent are from the other 70+ species.

On the basis of the information gathered from the regional reviews, Atlantic salmon is currently the most widely cage-reared fish species by volume and value; reported aquaculture production of this coldwater fish species increased over 4000-fold from only 294 tonnes in 1970 to 12 35 972 tonnes in 2005 (Valued at US$4 767 000 million), with significant production of more than 10 000 tonnes currently being restricted to a handful of countries, including Norway, Chile, the United Kingdom, Canada, and the Faroe Islands.

Most of the top marine and brackish cage aquaculture producers are found in temperate regions (Table 1), while the top species include salmonids, yellowtails, perch-like fishes and rockfishes (Table 2).

Table 1 Production of the top ten marine and brackish water cage aquaculture countries

Country	Quantity (Tonnes)	in percent of total
Norway	652 306	27.5
Chile	588 060	24.8
China	287 301	12.1
Japan	268 921	11.3
United Kingdom	131 481	5.5
Canada	98 441	4.2
Greece	76 212	3.2
Turkey	68 173	2.9
Republic of Korea	31 192	1.3

Table 2 Production (tonnes) of the top ten species / taxa in marine and brackish water cage aquaculture (excluding PR China)

Species	Quantity (tonnes)	in percent of total
Salmo salar	219 362	58.9
Oncorhynchus mykiss	195 035	9.4
Seriola quinqueradiata	159 798	7.4
Oncorhynchus kisutch	116 737	5.6
Sparus aurata	85 043	4.1
Pagrus aurata	82 083	4.0
Dicentrarchus labrax	44 282	2.1
Dicentrarchus spp	37 290	1.8
Oncorhynchus tshawytscha	23 747	1.2
Scorpaenidae	21 297	1.0

Integrated cage farming

Cage culture systems need to evolve further, either by going further offshore into deeper waters and more extreme operating conditions and by so doing minimizing environmental impacts through greater dilution and possible visual pollution or through integration with lower-trophic-level species such as seaweeds, molluscs and other benthic invertebrates.

The rationale behind the co-culture of lower-trophic- level species is that the waste outputs of one or more species groups (such a cage reared finfish) can be utilized as inputs by one or more other species groups, including seaweeds, filter feeding molluscs and /or benthic invertebrates such as sea cucumbers, annelids or echinoderms. However, while there has been some research undertaken using land based systems considerably, further research is required on open or offshore mariculture systems.

Prospects

Cage culture has great development potential. For example, intermediate family-scale cage culture is highly successful in many parts of Asia and one of the key issues for its continued growth and further development will not be how to promote but rather how to manage it. However, there is also an urgent need to reduce the current dependence of some forms of cage culture systems in Asia upon the use of low value/ trash fish feed inputs, including those for Pangasid catfish and high value species such as Mandarine fish, snakehead, crabs and marine finfish.

However, the intensive cage culture of high value finfish is growing fastest and there are important social and environmental consequences of this growth and transformation of the sub-sector. Similar to global tends in livestock production, there is a risk that the fast growth of intensive operations can marginalize small-scale producers and high production at different levels of intensity can lead to environmental degradation if not properly planned and managed. Considering that most of the cage aquaculture takes place in the fragile yet already much pressured coastal environments, there is increasing agreement that particular emphasis has to be given to the environmental sustainability of the sub-sector. Cage aquaculture will play an important role in the overall process of providing enough (and acceptable) fish for all, particularly because of the opportunities for the integration of species and production systems in near-shore areas as well as the possibilities for expansion with installation of cages far from the coast.

Even though the sea cage farming has been advancing in many Asia-Pacific countries such as China, Indonesia, Japan, Philippines, Taiwan, Vietnam and Korea in recent years, it still remains to be commercialised in India. The Central Marine Fisheries Research Institute has been taking pioneering and massive steps towards this direction currently. The major constraint for popularization of cage farming in India is the less availability of sheltered areas which are ideally suited for sea cage farming. In this context, the development of advanced types of mooring, anchor and floating systems which can withstand the impact of adverse weather and currents will help us to venture into more unsheltered open sea areas. Hence, it is felt that more technological and engineering interventions in cage farming coupled with large-scale hatchery production of high value and fast growing finfishes can pave the way for the development of sea cage farming industry in our country in near future.

Commercialization of Asian seabass, *Lates calcarifer* as a candidate species for cage culture in India

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Introduction

Asian Seabass *(Lates calcarifer)* a popular edible marine finfish commands consistent demand in domestic and international markets. It is widely distributed in Indo-Pacific region and extending up to Taiwan, South East Australian coast, Papua New Guinea, Arabian Sea and Bay of Bengal and further to Persian Gulf region. In India, seabass fishery is reported from all along the coast including Andaman & Nicobar Islands. Due to the characteristic catadromous pattern of life cycle, its population occupies a wide range of habitats starting from freshwater lakes, rivers, estuaries and inshore coastal waters. However, the adult fish migrate to deeper inshore sea areas for spawning and as such the early cycle is restricted in seawater areas. Besides, exploiting its natural resources from different environmental conditions, seabass become a compatible species for aquaculture in saline water as well as freshwater conditions.

Status of seabass culture in India

Asian Seabass in one of the prominent species being cultured in South East Asian Countries, China and Australia. Several commercial hatcheries produce seeds for aquaculture purpose in these countries and also evolved suitable feed for growing seabass in aquaculture systems. Besides, advances have been taken place in addressing health management challenges encountered while farming.

In India, seabass has been cultured in brackishwater and freshwater by stocking wild seed in some part of West Bengal, Tamil Nadu and Kerala. The cage culture of seabass is still in its developmental stages, even though the culture of seabass in different types of cages is now established by MPEDA (in ponds), RGCA (in ponds) and CMFRI (open waters). For the past five years, considerable development has been made in culture of the species in cages in ponds of all bio categories and hi-tech cages in open sea. But, many problems are remaining unsolved. Some problems encountered are:

i) Cannibalism during fingerling production from fry from 1.0-1.5 cm. to 6- 7 cm fingerlings

ii) Lack of availability weaning diet required for nursery rearing

iii) Non-availability of extruded pellet feed for grow-out

iv) Non availability of proper culture techniques in different bio categories.

Despite of all the above problems, the culture of seabass in cages in the pond or in the open water is being initiated and standardized according to the Indian conditions.

Culture technology for growing fish in cages in pond

Seabass can be cultured in freshwater or brackishwater ponds; but cannibalism is one of the most serious problems in seabass culture. In order to minimize the chances of cannibalism, culture is carried out in two phases, *i.e.* the nursery phase and grow-out phase.

Nursery phase

The main purpose of the nursery is to culture the fry from hatchery (1.5 – 2.5 cm) to juvenile size (6-7 cm). The nursery rearing can be carried out either in earthen ponds or hapas. Nursery pond size ranges from 1000 to 2000 m^2 with a water depth of 80 – 100 cm. Pond with separate inlet and an outlet gate to facilitate water exchange is recommended. Pond bottom should be flat and sloping towards the drainage gate. Inlet and outlet gates are provided with a fine screen (1 mm mesh size) to prevent predators and competitors from entering and the fry from escaping the pond. Fry ranging from 1.5 – 2.5 cm are suitable for stocking in nursery ponds. Stocking density is between 20 – 50 individuals per cubic meter. However, it is advantageous to conduct nursery rearing of seabass in hapas because it enables closer monitoring and grading resulting in uniform size stocking and better survival compared to open-pond rearing. It is likewise easy to maintain and require very little capital investment.

Table 1. Size of the fish and size of the feed

Size of the Fish(g)	Length(cm)	Size of feed(mm)	Type of feed
0.05 – 0.08	1.5 – 2.0	0.3 mm (Dust)	Slow sinking
0.08 – 0.40	2.1 – 3.0	0.5mm (Crumble)	Slow sinking
0.50 – 0.80	3.1 – 4.0	0.8mm (Crumble)	Slow sinking
0.90 – 1.65	4.1 – 5.0	1.0mm (Starter-1)	Slow sinking
1.70 – 2.60	5.1 – 6.0	1.2mm (Starter-2)	Slow sinking
2.70 – 4.00	6.1 – 7.0	1.5mm (Starter-3)	Slow sinking
5.00 – 7.00	7.1 – 8.0	1.5mm (Starter-3)	Slow sinking

Nursery rearing in cages

The seabass fry can be grown to fingerlings in net cages measuring 1 M x 1 M x 1 M, made up of HDPE. These net cages can be fixed in PVC frames of floating frame, sinker and top lid. Around 2000 – 3000 fry can be stocked and monitoring of the fries is easy in net cages. Also, the maintenance cost of the net cages is lesser than the hapas. The only constraint is that, a floating feed should be used in cages for rearing seabass. The mesh size of the cage is 2 mm, 4 mm, 6 mm and 8 mm. The fry will grow faster in net cages than hapas as it facilitates more aerations and water circulation movements inside the cages.

Food and feeding

During the nursery phase extruded slow sinking feed is preferred. Crumbled feed should be provided according to the requirements and subsequently the pellet size can be increased. The size of the pellet during the nursery phase is highly correlated with the mouth size of the seabass fry (Table 1).

The nursery period lasts for about 32 – 45 days until it reaches the fingerlings size (5 – 7 cm). During this period, water exchange should be done according to the requirements and water quality conditions. It is to be monitored that the minimum feed wastage is occurred so as to get profitable nursery rearing of seabass.

Grading

The mechanical grader available in the market can be used for grading the fries. Initially, once in three days and later weekly once the grading has to be done to separate the shooters and the bigger seabass fry. This exercise will give more survival rate with better growth as the seabass fries are getting the suitable feed according to their mouth size. Also, the cannibalistic characteristics drastically come down due to timely grading.

At the stage, the fingerlings are ready for transfer to grow-out system and this can be harvested from the hapas by scooping and transfer to grow-out ponds after proper counting so as to calculate the daily feeding regime.

For open sea cage culture, the seabass fingerlings grown to more than 7 - 10 cm or more than 10 – 15 g is ideal.

Grow-out phase

The most common grow-out system is pond culture, in either brackish or freshwater. A pond having minimum water depth of 6 – 8 feet is required for cage culture. Fish are usually maintained in cages within the pond, although cage culture of fish less than 120 – 150 mm TL and free-ranging of larger fish are sometimes combined (Schipp, 1996).

The cages are usually 4 – 5 m^2 (water surface area) and 2 – 4 m deep. They may hold 15 – 40 kg/m^3, provided they are cleaned off bio-fouling regularly, as poor water flow will stress the fish. Typically, the pond is aerated and receives water exchange of 5 – 10 per cent of pond volume per day, if necessary.

In India, a technology has been developed and perfected for culturing of seabass in cages in pond by RGCA, an R&D, the arm of the Marine Products Export Development Authority. In this method, the pond cages having the dimension of 2 M x 2 M x 1.3 M (approx. 5.0 Cu.M.) using PVC pipe frames of 40 mm (floating frame), 32 mm (sinker), 25 mm (top lid). The cages are fastened to the bamboo or wooden poles of the catwalks fixed in the ponds. The catwalks are provided for the purpose of day-to-day management activities, such as feeding, sampling, grading *etc.*

Seabass cages usually are made of Nylon or Polyethylene or HDPE Netting with varying mesh size depending on the size of the fish grown.

Table 2 Different cage mesh sizes and size of the fish to be stocked

Total Length of Fish (cm)	Cage Mesh Size (mm)
7 - 9	8
9 - 11	12
11 - 15	16
15 - 18	20
18 - 22	24
22 - 26	32
26 - 32	38
32 and above	44

The stocking densities in the cages vary according to the size of the fish, as the culture progresses and the fish grow in size the density has to be adjusted suitably. The suggested stocking densities are given below:

Table 3 Suggested stocking density in cages based on number/m^3

Size (cm)	Stocking density no./Cu.M.	
	With aeration	Without aeration
7.0 – 9.0	600	350
9.0 – 12.0	500	250
12.0 – 15.0	400	200
15.0 – 20.0	300	180
20.0 – 24.0	200	140
24.0 – 28.0	150	100
28.0 – 30.0	100	70
30.0 – 32.0	50	30
32.0 – 34.0	30	15

Feed

At present, seabass culture is facing the non-availability of floating extruded pellet feed which is the major constraint. However, few companies in India have come forward to manufacture feed for seabass culture, which is highly suitable for cage culture. Even though, trash fish are given widely for the culture at present in many places for sustainable aquaculture, the pellet feed is the highly recommended. The feed should be given twice daily in the morning hours, 6 – 7 A.M. and evening 6 – 7 P.M. at the rate of 8 – 10% total biomass in the first 2 months of culture. After 2 months, feeding is reduced to once daily and given during late evening at the rate of 2 – 5% of the total biomass. The floating pellet feed should be given only when the fish swim near the surface to eat. The suggested feeding schedule for extruded pellet feed is given below:

Table 4 Suggested feeding schedule, as % of body wt., type of feed, *etc.*

Size (cm)	Feed as % of body weight	Pellet Size (mm)	Type of feed
7 - 9	8.0	2	Slow sinking
10 - 12	7.0	2	Slow sinking
13 - 15	6.0	3	Slow sinking
15 - 18	5.0	5	Floating
18 - 20	4.0	5	Floating
20 - 22	3.5	7	Floating
22 - 25	3.0	7	Floating
25 - 27	2.6	9	Floating
27 - 30	2.2	9	Floating
30 - 35	2.0	11	Floating

F C R

For any aquaculture practice, the FCR is the determining factor for the economic viability of the fish culture for domestic or export and also the cost of production per unit. For seabass, 1: 1.2 FCR is recommended by using extruded pellet feed and 1: 5 – 7 is the observed FCR by using trash fish or farm made feed.

Production, harvest & marketing

In a 2 M x 2 M x 1.3 M cage, around 80 – 100 nos. is the recommended stocking density (biomass) in pond system. If fish is weighing an average 1 kg weight, around 100 nos. of fish can be stocked in the 5 m^3 area. The harvest of the fish grown in the cage can be done with minimum labors and effort. Around 10 tons production can be harvested within 3 – 5 hours from 100 cages. As the fish are grown in the cages is giving good muscle structure, taste and flavor, it is always fetching an average rate of Rs.150 – 180 in India (the price vary according to the local demand) and in export, fetching US$ 4 – 5 per kg.

Note: For open sea cage culture, the mesh size of the cage is same and only the width of the cage (circular or rectangular) will vary according to the stocking density and environmental conditions prevailing in the open sea. The frame for open sea cage culture, HDPE material is recommended. Stocking density, feed and feeding type and all other aspects are almost similar to the culture of seabass in cages in the pond.

Conclusion

In India, the aquaculture is centric to the shrimp/scampi production and these two species are contributing in total of 52% towards export. The freshwater fish produced through aquaculture is mainly catering to the domestic market only. In Indian seawater many finfish and shell fishes are abundant for aquaculture, which is economically important, the seabass (*Lates calcarifer*) fish is occupying the main role at present as it is a candidate species for cage culture as it has completed a value chain approach from seed production, nursery rearing, grow-out and marketing & export by MPEDA through its R&D Institute – RGCA.

Note: The above text and results presented here are based on the various demonstrations conducted on culture of seabass in cages in ponds by MPEDA-RGCA.

Engineering aspects to be taken care in cage culture of seabass (Cage designs and materials, Mooring materials, Net load calculations *etc.*)

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Aquaculture systems are very diverse in their design and function. The three most basic categories of culture systems are: i) Open systems, ii) Semi closed and iii) Closed systems.

Modern cage culture began in 1950's with the advent of synthetic materials for cage construction. The major advantage of cage culture is use of existing water bodies, technical simplicity, simplified harvest and low capital cost compared with land based farm. But it has got certain disadvantages like feed must be nutritionally balanced, pollution, out break of disease, vandalism *etc.*

Engineering considerations in the design of cages

The sea is perhaps the most difficult environment for Engineering. The sea can generate great storm forces on any floating or sea bed mounted structure and storm events occur randomly. The constant 24 hour per day bending compression and tension within structural member are optimum conditions for fatigue. Similarly constant motion in a corrosive fluid is ideal for mechanical wear and corrosion. Repairs and salvages are more difficult and in some cases access may be denied to some structures during a storm. Because of all these reasons the design of an aquaculture cage system is very complex in nature and of course the most difficult task. Hence, it is essential to select a proper site, ideal construction materials and proper designing, suitable mooring and good management *etc* in bringing out a cage culture production more profitable and economical.

Four different types of cages are fixed, floating, submersible and submerged (Fig. 1)

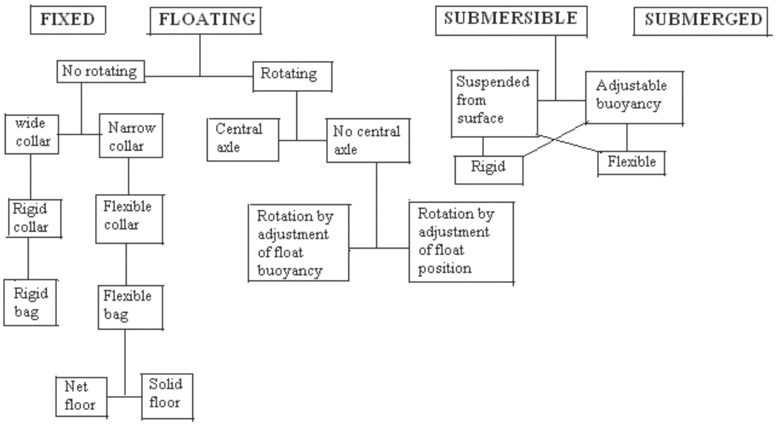


Fig. 1 Characteristics of different types of cages

Fixed cage consists of a net supported by posts driven into the bottom of a lake or river, they are completely inexpensive and simple to build, but their use is restricted to sheltered shallow sites with suitable substrates. The floating cages have a buoyant frame or collar that support the bag, they are less limited than most other cages in terms of site requirements and can be made in a great variety of designs ,and are the most widely used ones. The submersible cages rely on a frame or rigging to maintain shape. The advantage over other designs is that its position in the water column can be changed to take advantage of prevailing environmental conditions. Generally these cages are kept at the surface during calm weather and submerged during adverse weather. The submerged cages can be wooden boxes with gaps between the slots to facilitate water flow and are anchored to the substrate by posts or stones.

The major components of a cage farm are a) cage bag, b) floats, c) frame, d) service system, e) mooring system and f) anchor system.

The cage frame, nets used for cages and the mooring system has to withstand all types of weather conditions all year round. Net failure is an important source of fish loss in cage culture systems. So while making a net for a specific purpose many considerations are taken into account such as the forces applying on the net, the kind of materials the net and rope frame made from and the way in which they are tied. The main forces on any net structure are those arising from winds, waves and currents and from the interactions of the cage structure and its mooring systems with the resulting movement.

Cage bag

The three major functions of cage bag are a) keeping the fish stock together, b) protecting the stock against harmful external influences, and c) allowing free water exchange between the inside and outside water.

The net is normally flexible and made of synthetic nylon or polythene fibers reinforced with polythene ropes although recently new stronger materials like sapphire, Pectra or Dynema have appeared. The nets are stretched vertically with weight at the bottom of the cage or fastened by rope to the frame work. The tensile (breaking) strength of the nets can be tested to check its load carrying capacity by British Columbia Method, wherein a mesh is extended until it ruptures under the applied load. The apparatus used can indicate the load at the point of rupture. The testing machine is operated at rate of elongation which is both constant and within the prescribed limit.

One important aspect in the determination of cage bag size is stocking density and optimum carrying capacity. The shape of the cage is also another point under consideration. Observations made on the swimming behavior of the fish suggest that circular shapes are better in terms of utilization of space. Corners of rectangular shapes are little utilized. It is assumed that depths greater than 10-12 m would be poorly utilized by fish and a cage depth of 3-10 m be acceptable for most of the species. Circular cages are having least perimeter for a given area, hence reducing the material cost. Fig. 2 shows the perimeter lengths of different cage shapes for the same area of $16m^2$.

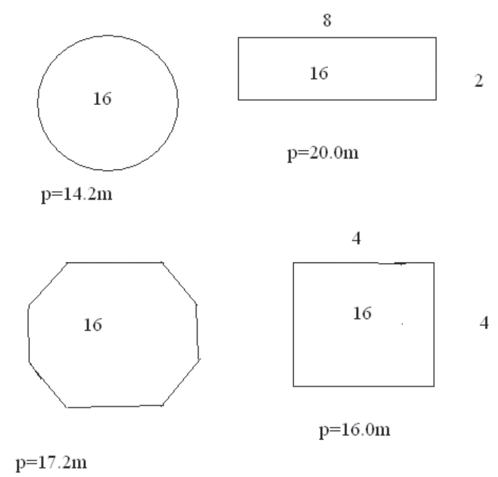


Fig. 2 Perimeter lengths of different cage shapes for $16m^2$ area

It is advisable to have the net meshes impregnated with a special anti-fouling material to prevent biofouling. The upper side of the cage bag above the surface is joined to the hangers in the brackets near the hand rail for lateral protection. Surrounding vertical and horizontal ropes which are used for joining the net to the rings reinforces the cage bag. The cage bag comprise two nets one inner net in which fishes are placed and an outer or predator net to protect the fishes from predators. A bird net also is provided for protecting it from fish eating birds.

Floats

Floats provide buoyancy and hold the system at a suitable level in the surface of the water. This also holds the shape of the cage structure. Common floatation materials include metal or plastic drums, HDPE pipes, rubber tiers and metal drums coated with tar or fiberglass. Fiberglass drums are preferred as they can last for many years although the initial cost is comparatively high. Styrofoam blocks covered with polyethylene sheets provide good buoyancy. The buoyant force varies depending of size and materials used.

Frame

The frame can be made of galvanized steel aluminum, timber and different plastic materials. The frame should be mechanically strong, resistant against corrosion and easily repairable or replaceable. The cage has collars of HDPE for structure and the same time for floatation and for ballast. The HDPE pipes are highly flexible structure and are used in most of the circular cages. The cage has two floatation pipes filled by expanded polystyrene as a precaution in case of damage avoiding loss of floatation force. The ballast pipe will have holes for the free flow of water and metal lines are used inside for increasing weight. The hand rail pipe will not have any material inside. The pipe ends will be jointed by using a welding process for plastics.

The two pipe rings for floatation and brackets will join the hand rail. These brackets will give support to the rings and at the same time it will form a part of the catwalk. The brackets made of galvanized steel to avoid corrosion and be fitted to the diameter of the pipes. The maximum height of hand rail should be approximately 100 cm and minimum width for cat walk approximately 60 cm.

Service systems

This is the system required for providing operating and maintenance services, for *e.g.* feeding, cleaning, monitoring or grading. One way to provide this is by a catwalk around the cage. Some cages use their floatation collars made of metal or plastic pipes with or without additional internal or external floats. But polyethylene has the strength, flexibility and lightness necessary for the catwalk in the cage.

Mooring system

This holds the cage in suitable position according to the direction and depth decided in the design. The mooring joints the cage with the anchor system. A mooring system must be powerful enough to resist the worst possible combination of the forces of current, wind and waves without moving the break up. Wind and current forces are proportional to the square of the velocity. Thus an increase in current from 1 knot to 2 knot will generate 4 times the drag on a rigid submerged body. A change in the mooring system will change internal load on the cage system. Wave forces are much more difficult to compute because the dynamic response of the system depends on so many factors. The materials used in the mooring line are sea steel lines, chains, reinforced plastic ropes and mechanical connectors. The mooring force capacity depends on both the material and size and can be adjusted to the requirements. Attachments to the system are by mechanical connectors and ties.

Two types of mooring systems commonly used are multiple points and single point. The former is more common and involves securing the cage in one particular orientation while with the latter the cages are moored from one point only, allowing them to move in a complete circle. Single point mooring tends to be used with rigid collars. They use less cable and chain than multiple point mooring and, because they adopt a position of least resistance to the prevailing wind, wave and current forces, both inter cage forces and tortional forces at linkages are reduced. Single point mooring system also reduces the enormous net deformation than the conventional mooring system. They distribute wastes over a considerably larger area than those secured by a multiple point system. Fig. 3 & 4 shows single and multiple point mooring systems.

To avoid the possibility of bag shape deformation caused by possible high currents, the mooring uses a system of six joint points to the cage, three in the upper side to the floating pipe and the other three in the lower side attached to the ballast. This connection up and down in the cage assures to maintain the shape in position irrespective of the currents. The orientation of cages with multiple mooring depends on the nature of the site and the type and group configurations of the cages. If the currents are strong it may be best to secure cages in the position of least resistance to the prevailing wind and current force,

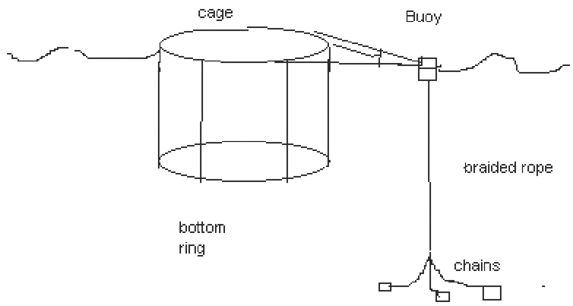


Fig. 3 Single point mooring system

There are a variety of methods of using a single and multiple point moorings.

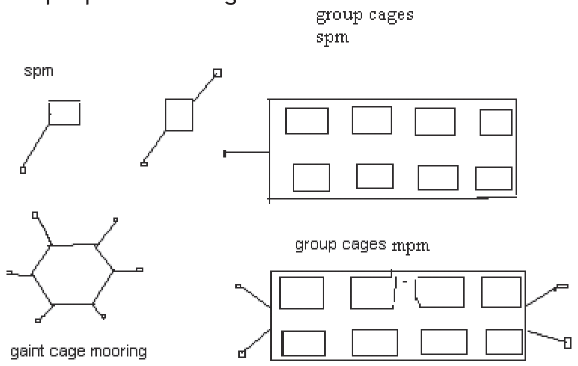


Fig. 4 Multiple point mooring system

Mooring line must perform two functions: they must withstand and transmit forces. The loads imposed on a cage mooring system are principally dynamic. It is important that mooring line must have a high breaking strength and can absorb much of the kinetic energy of rapidly changing forces (wave and wind) otherwise these forces will be directly transmitted to anchors. Chains are used as mooring line, it is extremely stronger but it is heavy and used in conjunction with synthetic fiber rope, Synthetic fiber ropes are composed of nylon, PE, PES, PP *etc.* Stainless steel chain is suitable for marine use, but it is expensive. Mild steel chain with low carbon and manganese contents has been widely recommended for cage anchorages.

Total length of the mooring line should be at least three times the maximum depth of water at the site and where the rope joins the chain a galvanized heavy duty thimble should be spliced in to the rope and a galvanized shackle of the appropriate size used to connect the chain to the rope. The chain is connected from the anchor to a float positioned 10 m or so from the cage and a section of rope is used to link the float to the cage. The buoy minimizes the vertical loading on the cages and must be sufficiently large to support the mass of the chain and to resist the vertical forces imposed by the cages on the mooring system. Under shock loads, the chain /buoy acts as a spring absorbing much of the energy that would otherwise be transmitted to the anchor. The possible shock loads can be counteracted using a system of hung weights located between the multi connector pipe and the anchor. This system ensures soft movements of the cage with the current by absorbing possible shocks. The vertical position of the weights depends on the forces acting upon it, thus operating as a shock absorber.

Anchor system

The simplest and cheapest type of marine anchor is the dead weight or block anchors, which typically consist of a bag of sand or stones or a block of concrete or scrap metal. Concrete block anchors may simply be fabricated with reinforcement. The anchor is connected to the mooring system by chains and ropes. The anchor system is normally formed by a system of concrete blocks joined together, by chains and connected to a buoy by a braided rope. Several concrete blocks instead of one, make the setting of the system easy. These mooring and anchor systems allow the cage to be disconnected easily and quickly in case of bad weather and the cage can be towed to a safe place without loosing its shape.

Mooring maintenance

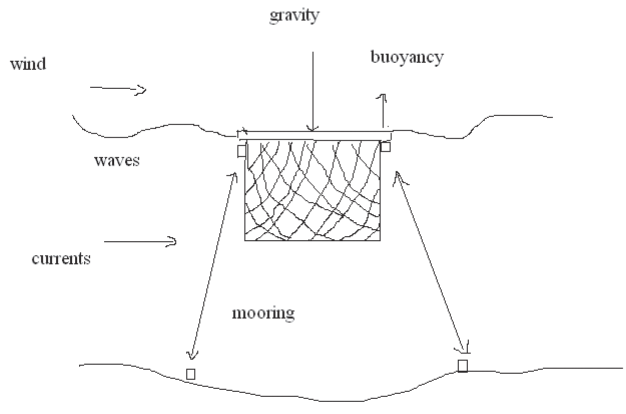
Cage mooring is a dynamic system which must respond to motion under load every minute of the period for which it is established. Maintenance is critical to ensure that components are physically sound and that linkages secure. Wear and tear of the parts namely chain links, brackets, shackles, splicing eyes, need to be checked periodically and bolts and shackle pins need to be tightened. Proper maintenances of the entire system gives more life to cages.

Specifications of the CMFRI cage at Munambam, Kochi

The chosen site was having an average velocity of current 1m/s, depth 10 m, and muddy sea bottom. The loads were divided in to two types:

a) Static loads, which are vertical and are caused by the action gravity with reaction in the buoyancy of the cage. These depend on the area and density of the netting, weights of the frame components, weight of rigging, weight of the ballast and opposition in the floatation force.

b) Dynamic loads, which are mainly horizontals and are caused by the current, winds and waves with reaction in the moorings and anchors of the cage. These depend on the materials used, shape of the panel, size of the mesh, current velocity and density of water.



principle forces acting on acage system

To compute the static loads in the cage the relation between the weight of the cage with its components like the descendent force and the capacity of floatation the ascendant force was estimated. The weight was computed for three conditions:

a) Clean cage in air
b) Clean cage in water
c) Foul cage in water

In order to compute the weight of the cage in water, the densities of the materials used must be established. For the cage to float, the static loads acting on the structure (*i.e.* weight in water) must be counterbalanced by buoyancy forces. The buoyancy of the collar is dependent upon the upward force acting on those components wholly or partially immersed in water and is equal to the weight of water displaced.

The buoyant forces can be calculated by using the formula:

F_B = Vw Qw-Vm Qm

F_B = buoyant force (kg)

Vw & Vm are the are the volumes of water and floatation material (m^3)

Qw & Qm are the densities of water and floatation material (kg/ m^3)

The loads caused by the currents, wind and waves against the cage were considered to be the dynamic forces. These forces act on different parts of the cage, but all of them drag and deform its shape. The knowledge of these forces is required for the computation of the mooring and anchoring system. The current act mainly on the cage bag and rigging under the water, the load depends on the current velocity, density of water, material, shape and size of mesh. Water flowing through a mesh or netting imposes loads which are transmitted to the supporting frame, collar and mooring system.

Wind and current forces are proportional to the square of the velocity. Thus an increase in current from 1 knot to 2 knot will generate 4 times the drag on the rigid submerged body. Wind forces act mainly on the cage superstructure formed by hand rail, brackets and free board netting.

The general equation to calculate the current drag is

Fx = 1/2 Cd.μAv² (expressed in KN)

Where Fx = current drag

Cd = coefficient of drag

p = density of sea water in T/m³

A = area normal to flow in m²

V = incident current velocity m/s

The wave forces acts mainly in the ring area of the cage. It is very difficult to compute the wave forces as the dynamic response of the system depends on so many factors. To calculate it, the horizontal and vertical orbital velocities of the water particles must be known. These can be derived from the information on prevailing wave periods, wave height and water depth at the site.

Wave force (Fw) = Kd.*p*μ²A

Where Kd is the coefficient similar to Cd in netting whose value depends on the material and shape of the collar

p = density of sea water

μ = horizontal component of wave particle orbital velocity (for marine cage it s taken as 2m/s)

A = area of the cage collar perpendicular to the wave train

The moorings and anchor system and their components were proposed based upon the calculated forces on the cage. For a particular current velocity a fouled cage with total load (sum of the loads acting on each component) was calculated. Based upon the maximum load estimated a gabion box made of PP with copper lining containing three compartments of 1t each (total 3t) capacity was filled with stones and used as the mooring system. Specifications of other materials used for the cage are given in Table 1.

Table 1 Specifications of the parts used:

Part	Material	Size /quantity
Floating pipe innerFilled with PUF	HDPE140mmø 10kg/cm²(PE100 grade material	6m dia
Floating pipe outer	HDPE140mmø 10kg/cm²(PE100 grade material	8m dia
Middle ring	HDPE90mmø 10kg/cm²(PE100 grade material	catwalk
Base supports	250mm,HDPE	8 nos.
Vertical supportsFixed with T joints , using fusion welding as well as with SS bolts and nuts	90mm,HDPE	0.8 m height16 hooks
Diagonal support	90 mm, HDPE 10 kg pressure	8 nos
Buoys,filled withPUF,	350mm dia with end caps(10 kg)	
Mooring clamps	14mm,4"mooring clamps	3 nos
Mooring chainMS	10mm	
Ballast pipe	HDPE,63 mm ,circular	8m dia
Mooring swivel	MS	
Outer net, Braided HDPE, 3mm/80mm square mesh	Provided with SS rings of 12mm thickness,for connecting to the cage frame	7m dia&5m depth, 18 rings bottom12 ring top
Inner net, Twisted HDPE net 1.25 mm/30-35mm mesh size	With SS rings	6m dia & 5.3 m depth12 rings top
Bird net,1.25mm/80 mm twisted HDPE	6m dia	
Hapa,Nylon with 8/10 mm mesh	2.5x2.5x3 m rectangular shape	
Chain 80 grade MS 10mm	3T working load,7T stretching load,11 breaking load	
D shackle 1'',1/2''&3/4" MS	(3T,0.5T,3Tworking load)	
Swivel 1'' forged steel 80 grade	3T working load	
Solar blinkers	Water proof shock resistant red colour blinking light	3 Nos

Netting specifications and maintenance of cages for finfish culture

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A cage is a space enclosed with some type of mesh forming a container for aquatic animals to grow. It is typically box-shaped or tube like structure with a rope system which supports the netting material, gives shape and allows for tying to the raft unit. In box type cages, the cage is constructed of four panels at the sides and one bottom panel. Anti-predator nets are deployed around the cage to prevent entrance of predators such as sharks and sea lions into the cages. An additional net would be provided on top of the cage to prevent bird predation.

Types of net cages

The cages usually are of two types: fixed and floating. The floating cages are interlocking cages suspended in a bamboo/wooden/ polyethylene frame. The cage is floated by either bamboo raft or styrofoam floats, and is held in place by heavy anchors.

The dimensions and mesh sizes of the cages are dependent on the species cultured and size. The mesh sizes of the cages depend upon the type of cage. In Japan, circular and square/ rectangular floating cages are used, whereas in Norway floating cages are not only circular, square/rectangular, but may also be hexagonally shaped. Cages that are either cylindrical or spherical are used in West Germany. In Singapore, the farmers use the more conventional square (cuboidal) cages. The square type usually measure 2×2, 3×3 or 5×5 m, with a depth of 2-3 m while rectangular types are 6×3 m, with a depth of 3 m. In Korea, the floating cage system consists of the cage and a frame to support the nets. In India, rectangular cages of 10mx5mx2.5m are used for the culture of Indian major carps.

Basically there are 3 types of cages:

Hapa cage is for stocking of the fish during the early nursery phase (Fingerlings to a Total Length of about 10 cm). This is made of very fine-meshed nylon net. It is used for rearing fry to fingerlings. Fry measuring 1–6 cm are initially stocked in this cage.

Nursery cage is used during the later nursery phase. Usually PE net is used for the net bag. This cage is stocked with 10 cm fingerlings till they reach a size range of 15–20 cm.

Grow-out cage is used for the grow-cut phase where the cultured fish reach marketable size of 30 cm and beyond. The netting used is usually PE net.

Broodstock require cages of mesh sizes larger than 50 mm.

The rope which is used for the main and hanging lines of the hapa and nursery cages is PP/PE rope (6 mm diameter), while for the grow-out cages, PP/PE rope of 10 mm diameter is used.

The frame which is used to hold the interlocked cages together in place also serves as a catwalk and working platform. A frame made of bamboo is preferred over a wooden one mainly due to economic reasons. Besides, the bamboo frame also acts as a floatation device.

As net bags are subject to damage by floating debris, large carnivorous animals and other agents, often a second larger mesh net is used outside the net to provide mechanical protection for the confinement net. The two nets must be placed in such a way that they do not rub each other, or one or both nets will be damaged by abrasion. E.g: the outer netting can be of HDPE braided twine of 3 mm diameter and mesh size 80 mm. There can be an upper selvedge of netting made of HDPE of 4 mm diameter braided twine of the same mesh size and 80 mm mesh size. This selvedge portion should be of 0.5 meter stretched length or equal to the length of the brackets/rings above the upper ring structure whichever is larger. Inner netting can be of HDPE twisted twine of 1.25 mm diameter and of mesh size 25 mm. An upper selvedge of netting made of HDPE twine of 2 mm diameter and with 25 mm meshsize. This selvedge portion should be of 0.5 meter stretched length or equal to the length of the brackets/rings above the upper ring structure whichever is larger.

Design Considerations

Designing of net structures require several forces to be considered; the main being static and dynamic loads. Static loads include the weight of the structure (net, support, and other structural parts), and added loads due to maintenance and operations. Dynamic loads include forces generated by wind above the water surface, waves at the air-water interface, and currents (particularly tidal currents) in the water. Additional dynamic loads may be encountered due to collection of floating debris, collision with water craft or large predators or other similar conditions. Effects of corrosion and fouling add to it. Wave forces on a net impoundment structure are based on the highest wave expected to occur in the design life of the structure. As fouling or surface debris drastically affect the coefficient of drag, this factor must be considered. Fouled nets create twice the resistance to tidal current as the same net when clean (Milne, 1970). The nets must be designed to withstand the sum of the forces, assuming that all the forces are at some moment acting in the same direction. If two nets are used, loads on the supporting structures will be the sum of the loads imposed by each net.

The aquacultural net enclosures should have good tidal flushing. Water flowing through the net will impose loads on the net and supporting or mooring structure. Kawakami (1964) developed the following Equation 12.9 to describe the load imposed on net structures due to flow at right angles to the net. The force on 2.50 cm mesh nylon net by a 1 m/s current is 0.42 N/mesh in the unfouled condition and 5.1 N/mesh after one month of immersion in sea water.

Nets enclosing fish are subject to damage by floating debris, large carnivorous animals and other agents. A relatively small hole in the enclosure net can result in loss of nearly all the fish. Hence, it is often wise to use a second larger mesh net outside the confinement net to provide mechanical protection for the confinement net. The two nets must be placed in such a way that they do not rub each other, or one or both nets will be damaged by abrasion. As all nets require periodic maintenance for cleaning or repair before design it must be decided whether the panels will be pulled out of the water for this work or divers will be used. If the panels must be removed from the water, some means to prevent fish escape will be necessary. The panels must also be small enough to be manipulated by the handling technique chosen. Panel weight will be actual panel weight plus weight of fouling. The following factors are generally considered in the design and operation of culture cages:

- It is advisable to put floating cages underwater to avoid wind action and also to reduce algal growth
- Use cage materials available within the locality to reduce the costs
- Before setting out the antifouling impregnated nets they should be dried so that the antifouling stays on the net.
- Consider the cost and durability of the materials
- Net size: It is better to design the size of net cage to suit the breadth of the netting rather than on a preselected size.
- Size of species: Net mesh should be smaller than the fish size to avoid escape of the fish through the meshes.
- Nets should have sufficient strength to withstand different forces encountered
- Net bag should have suffiecient looseness. To get a uniform spreading and flexibility to the bag 20-30% of excess net is to be used than the actual cage size
- Aeration can enhance water quality, reduce stress, improve feed conversion efficiency and increase growth and production rates. Aeration can improve cage production by 20 percent or more.
- Leave at least 10 feet between cages and keep cages away from weed beds. Weed beds and overhanging trees can reduce wind circulation and potentially cause problems.

Netting materials for cage construction

Netting yarn is a textile product suitable for the manufacture of netting and can be knitted into netting by machine or by hand without having to undergo further process. Yarn is made into a netting by twisting or braiding. Monofilaments are used directly for making into netting without further process, hence it follows that monofilament yarn is a netting yarn also. The Twisted netting yarns (netting twines) are made by a series of processes.

- Fibres twisted together to form a single yarn.
- A number of single yarns are twisted together to form a strand or ply.
- Three strands or ply are twisted together to form a netting twine.

Synthetic materials are predominantly used for construction of net cages. Synthetic fibres are produced entirely by chemical process or synthesis from simple basic substances such as phenol, benzene, acetylene *etc.* As compared with vegetable fibres, they have better uniformity, continuity, higher breaking strength and are more resistant to biodegradation. Depending on the type of polymer, synthetics are classified into different groups and are known by different names in different countries. Altogether 7 groups are developed; polyamide (PA), polyethylene (PE), polypropylene (PP), polyester (PES), polyvinyl chloride (PVC), polyvinylidene chloride (PVD) and polyvinyl alcohol (PVAA).

The synthetic netting yarns used in Indian fisheries sector are polyamide, polyethylene and polypropylene. PA and PE are the most commonly used fibres for netting while PP and PE are used for ropes. The material strength of net panels when exposed to sunlight (UV), wind, rain, acid rain, *etc.* get reduced. This process is called weathering. Even though all fibres, irrespective of natural or synthetic are prone to degradation on exposure to weathering, the problem is severe with synthetic fibres. The main factor responsible for weathering is the sunlight, *i.e.* the ultra violet part of the sun's radiation. Polyvinyl chloride (PVC) is the material that is most resistant to weathering, followed by PE and PA; PP has the shortest lifetime. The lifetime can be increased by adding a coloured (black) antioxidant, so that development of weathering is reduced. The resistance of netting materials to abrasion, *i.e.*, abrasion with hard substances such as frames, sea bottom and net haulers, or abrasion between yarns/twines is important in determining the life of a net.

Another material recently introduced is Ultra high molecular weight polyethylene (UHMWPE) available as Dyneema. It is very advantageous as aquaculture nets due to the low diameter, favorable weight/strength ratio, low elongation and nil shrinkage in water which helps the mesh size to remain stable during normal use of the netting. The resistance of Dyneema nets to UV light and abrasion is high, guaranteeing that nets last longer.

Selection of netting material

The following factors are to be considered for selection of suitable net material for the construction of cages: Synthetic fibres are preferred over artificial or natural fibres because of their durability and strength.

- Cages made of synthetic fibres are convenient to use as they can be easily folded and are light to handle. They are also easy to install and to remove. It is not surprising that many floating farms use such materials rather than rigid metal cages for rearing the fish

- The netting yarn should maintain its shape, *e.g.* monofilament netting, suitable for gill-netting, is not suitable as cage material as it tangles and folds up easily

- The material should be durable, resistant to abrasion and has high breaking strength

- The material should not be so heavy as to make handling difficult *e.g.* thicker netting material even though durable and resistant to crab bites/abrasion would be heavy at cleaning time especially when it is fouled.

- With the exception of the hapa net, cages are usually constructed of polyethylene (PE) material. Polyethylene is preferred for its high breaking strength, durability, high resistance to abrasion and cheaper cost when compared with other available materials like polyamide, polyester, polypropylene *etc.*

- Polymide (PA) and polyethylene (PE) netting are readily available locally. Knotless polyamide netting of 210Dx2x2 is popular for making cages that are to be used for stocking young fish fingerlings and prawns as the material has a smooth surface and there is minimal abrasion on the fish when the cage is lifted up during net change. PA is expensive and costs about Rs. 350-470/kg. However, it has a very high breaking strength and abrasion resistance. Its fibre deteriorates if subjected to prolonged direct sunlight and hence it is classified as having medium durability. The material being soft, can also be cut through by crabs and fish with strong dentition and the cultured fish can escape through gaps made in the cage

- Polythylene netting is generally preferred by cage operators because it is cheaper and protects better against damage caused by crabs and fish, although large-sized crabs can still bite through the material. It is the cheapest of the synthetic netting materials available, priced at around Rs. 200-275/kg, *viz.* around half the price of PA netting

- PE netting is available in various specifications of Denier and ply and also in knotless and knotted forms. The type that is selected would depend on the species and size of fish stocked. PE has also high breaking strength and abrasion resistance. However, like PA, it is to be stored away from direct sunlight, viz. in the shade. When used at the farm, the portion of the cage above water lasts for 3 years, whereas the rest of the cage which is submerged in the water lasts for 5 or more years. PE netting is usually for making cages for nursery and grow-out fish while for hapa, PA is preferred

Table below lists the synthetic fibres that are suitable for use as fish cages.

Table 1 Comparison of important characteristics of synthetic fibres

Properties	PA	PE	PP	PVC	PES	PVD	PVA
Specific gravity	1.14	0.96	0.91	1.35-1.38	1.38	1.70	1.30
Melting point °C	240-250	125-140	160-175	180-190	250-266	170-175	220-230
Durability	Medium	Medium	Poor	Very high	High	High	High
Breaking strength	Very high	High	Very high	Low	High	Low	Medium
Extensibility (wet)	High	Medium	Low	High	Low	High	High
Resistance against weathering	Medium	Medium	Low	Very high	High	High	High
Abrasion resistance	Very high	High	Medium	High	High	High	High
Cost	Very high	Low	High	High	Very high	High	High

polyamide (PA) is the most commonly used material for the fabrication of net bags, as the material is strong and not too stiff to work with. PE is also used to some extent because it is more resistant to fouling as the surface is smoother: however, it is stiffer to work with. Polyester (PES) has also been tried. Nylon used for nets is made as a multifilament twine consisting of several thin threads spun together to make a thicker one. The advantage with multifilament is that the thread is easy to bend, easy to work with, tolerates more loads and is more resistant to wear/rubbing. In contrast, monofilament is a single thread as used in a fishing line. It can be made of PE; it is stiffer and more vulnerable to chafing than a multifilament. Nets are either knotted or knotless.

Mesh size

Mesh size can be described in many ways. Bar length is the distance between two knots while mesh size is the distance between the knots on a stretched mesh (Fig. 1). In a hexagonal mesh, the mesh size is given as the distance between the two longest parallel bars. Mesh size may, however also refer to bar length, which makes this expression rather confusing.

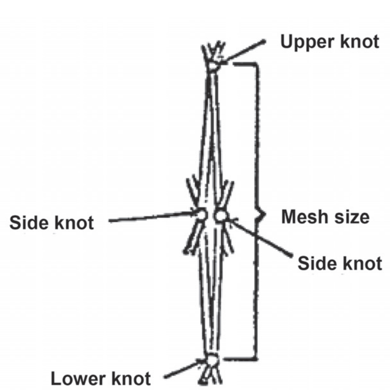

Fig. 1. Mesh size

Another factor which decides how the net panel is standing in water is how the net is stretched in the length and depth wise directions. This is called the hanging ratio of the net (E) which is the ratio between the length of the stretched net panel (Lm) and the length of the rope/ line where the net is fixed (top line) (L):

$$E = L / Lm$$

Normally E for net bags for fish farming is in the range 0.6 – 0.9, while for a fishing net, E is between 0.4 and 0.6, meaning that netting of cages have meshes that are more stretched out (Fig. 2).

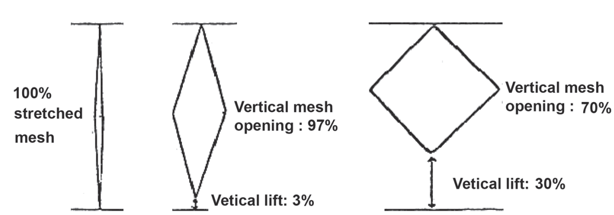

Fig. 2. Hanging ratio and corresponding vertical mesh opening

Solidity is used to describe the 'tightness' of a net. This is the ratio between the total area that the net covers, compared to the area covered with threads including knots. This relation is important when the resistance against water flow through the net is to be calculated.

Fouling on the net will increase the solidity, because the covered area is increased.

Mesh-size selection is dependent on the species and size to be stocked. The seabass, having a more pointed snout would require a cage of smaller mesh-size than would a grouper of the same size. The relationship between cage mesh size and a few fish species are summarized in Table 2 and recommended material amd mesh size for different cage types are given in Table 3.

Factors to be considered for mesh size selection

- Mesh size should not be less than 10 mm to assure good water circulation through the cage while holding relatively small fingerlings (10 to 12.5 cm) at the start of the production cycle.
- The meshes of the cage should remain open completely in water to form a diamond-shaped hole so as to allow good water exchange with minimum use of netting material
- Meshes should not be large enough to gill the fish stocked
- Mesh size should be roughly equal to about 25% of the body length of the fish

Construction of cages

Hapa cages

The dimensions of the hapa cage can range from 2×2×2 m to 3×3×3 m to 5×5×2-3 m depending on the scale of stocking. Mesh size can range from 8 mm to 9.5 mm

Table 2 Relationship between cage mesh size and fish species

Type of cage and netting material	Mesh-size (cm)	Grouper, TL (cm) (*Epinephelus tauvina*)						Seabass, TL (cm) (*Lates calcarifer*)				Snapper TL (cm) (*Lutjanus johni*)			
		5–10	10–15	15–40	40–50	50–75	75 and > Broodstock	7.5–10	10–25	25–30	>30 Broodstock	5–10	10–15	15–20	50 and > Broodstock
Hapa (PA 4 ply)	8	+						+				+			
Nursery (PE 15 ply)	13		+						+				+		
	25			+						+				+	
Production (PE 24 ply)	25			+							+			+	
	50				+									+	+
	75					+									
	100						+								

(Source: FAO, 1988)

Table 3 Recommended material and mesh size specifications for different cage types

Cage	Recommended material specifications	Mesh Size (mm)	Fish size recommended(TL, cm) Grouper	Seabass
Hapa	Polyamide (nylon) 210D/2x21200 meshes deep.	9	5–10	10 and <
Nursery	Polyethylene, 380D/2x3300 meshes deep.	9.5	10–15	10–15
	Polyethylene, 380D/3x3 or 5x3300 meshes deep.	12.7	10–15	10–15
	Polyethylene, 380D/5x3 or 6x3300 meshes deep.	19.1	15–30	15–20
	Polyethylene, 380D/6x3 or 7x3300 meshes deep.	25.4	15–40	20–30
Grow-out	Polyethylene, 380D/7x3 or 8x3300 meshes deep.	25.4	15 – 40	>30
	Polyethylene, 380D/9x3300 meshes deep.	38.1	15–40	>30
	Polyethylene, 380D/10x3 or 11x3300 meshes deep.	5.8	40–50	-

depending on the initial size of fry/fingerling stocked. The hapa cage is usually constructed of knotless material, *e.g.*, PA, so as to avoid any abrasion to the fish fingerlings during hauling of the cage. Knotted netting should be avoided as far as possible as the abrasions caused to the fingerlings could result in disease, especially bacterial infection. Besides, small-mesh knotted netting materials are also heavy and easily fouled as fouling organisms tend to be congregated to the knots. Main rope is made from PP/PE of 5–6 mm diameter. Bolch line is usually made of PP/PE of 2 – 3 mm diameter. PA netting twine of 210D/9x3 is used for hitching the bolch line to the main rope, and 210D/6x3 is used for joining the netting material/panels/sections to the bolch line.

Nursery cage

Like the hapa, the nursery cage can be of 2×2×2 m, or 3×3×3 m, or 5×5× 2-3 m, depending on the scale of stocking. The netting material used is usually of the knotted type. Polythylene (PE) is usually selected. Mesh size can range from 9.5 mm (3/8") to 25.4 mm (1") depending on size and type of fish stocked. Main rope is PP/PE of 8 mm diameter while bolch line is also PP/PE of 2mm diameter. PE twine of 380D/4x3 is used for joining the netting panels and 380D/6x3 or 7x3 is used for joining the bolch line to the main rope.

Grow-out cage

Cage dimensions of grow-out cages are similar to hapa and nursery cages. Like the nursery cage, grow-out cages are also constructed of knotted netting, usually of PE material. Mesh sizes start from 25.4 mm (1") and mesh size to be selected depends on the size of fish stocked. Larger sized fish of 30 cm could be stocked in cages of mesh size 50.8 mm. The main rope is PE of diameter 10 mm. Bolch line, as for nursery cages, is of PP/PE of 3 mm diameter.

Factors to be considered for cage construction

- The net panels should be cut such that there is minimum wastage of netting material
- The dimensions of the cage should be slightly smaller than the floating frame on which it is suspended so that the cage fits well within the frame.
- Cutting: Synthetic nets are to be cut by calculating the meshes required that would give the desired vertical mesh opening or hanging. Stretching the material to the actual cage dimension will result in uneven measurements and irregular fit.
- Vertical mesh opening or hang-in of the netting must be pre-determined. The vertical mesh opening or hang-in of the netting is defined as the mesh size of the netting at free hanging and is expressed as a percentage.
- A vertical mesh opening or hanging of about 70 % is recommended for cages as the mesh then approaches that of a square as seen in Fig. 2.

The side net panels are joined to the bottom panel by sewing with twine. Sewing is done by passing the twine along the outer edges of the two panels in a 1 mesh side to 1 mesh bottom ratio. For every 5 stitches, an overhand knot is made. A bolch line is to allow the attachment of the main rope to the netting material. It is passed along the 4 bottom seams of the cage between the side panels and bottom panel (basal bolch) and along the top square of the side panels (top bolch). Threading is done through each mesh, if necessary. The bolch line is a thin rope whose diameter varies according to the netting material used.

The main rope is used for giving the cage its shape and for suspending the cages. It is sewn on to the bolch line. It is of a larger diameter than the bolch line and its size, like the bolch line, varies according to the netting material used for the construction of the cage

Maintenance of the cage

The normal lifetime of a net bag will vary with the site conditions.. As a general rule, if the breaking strength of the net bag below the surface falls below 65% of the initial strength it is considered as unserviceable. With proper care, cleaning and repair, the economic life of polyethylene nets ranged from two to five years. The small mesh size net of less than 2.4 cm foul more rapidly and has to be cleaned more frequently. In temperate regions, the life time of a net bag is usually 5 years.

Biofouling

Biofouling is a major problem in cage culture during summer months especially at marine sites. Biofouling occurs as a result of the settlement and growth of sedentary and semi-sedentary organisms like barnacles, tunicates, tube worms, mussels, bryozoans and algae on artificial structures placed in water. It mostly composed of organisms with organic or mineral material trapped in between. Floating cage culture using nets is particularly vulnerable during the hot season. Although biofouling of artificial substrates has been well studied, biofouling pertaining to the aquaculture environment and biofouling on cages in tropical marine waters is less studied. The frequent cleaning of nets is not only costly and labour intensive but often gives rise to loss of stocked fish due to net changes and damage. Uncleaned nets on the other hand can cause severe physical stress on the cage nettings during strong current flow when they could tear. Fouling significantly impedes the water flow and therefore the supply of dissolved oxygen to the caged fish. Fouled netting also increases structural fatigue on cages and the fouling communities may harbour disease-causing microorganisms. Hydrodynamic forces on a fouled net can be 12.5 times that of a clean net. Concurrently, the weight of cages can increase sever-fold, causing further structural stress as well as a reduction in cage buoyancy and increased net deformation. Retarded water flow and inorganic and organic enrichment through fish feeds and faecal matter enhance the macrofouling assemblage on fish netting. The structure, colonization dynamics and depth distribution of the macrofouling assemblage are affected by salinity, water depth and substrate area and immersion period.

Multifilament netting material is particularly vulnerable to fouling, as it is non-toxic, contains many crevices that can entrap and protect settling organisms, and has a high surface-area to volume ratio. The materials used for making the nets (metal, synthetic materials) and their form (galvanized panels or nets) also affect fouling levels. Galvanized panels developed much less fouling than the synthetic fibre netting panels. Since fouling encrusts small mesh nets more rapidly, the fish farmer should use the largest mesh size permitted by the size of the fish. Netting colour significantly affected the growth and composition of algal fouling, but had no effect on invertebrate fouling.

Fouling Control

The prevention of fouling on mariculture structures is complicated by the choice of net material and the dangers of toxins to cultured species. Antifouling practices include predominantly the use of copper-based antifouling coatings. There have been incidents where antifouling has adversely affected fish: in the 1980s, trials with tributyl-tin on cages caused significant effects to farmed salmon. The antifouling solutions presently available are not ideal, and it is widely accepted that there is an urgent need for research into anti-fouling technologies. Such alternatives include the adoption of "foul-release" technologies and "biological control" through the use of polyculture systems. However, none of these have, as yet, been proven satisfactory. In view of current legislative trends and the possible future "phasing out" of available antifouling materials, there is a need to find alternative strategies. The use of most commercially available, antifouling chemicals or coatings on cage nettings is largely restricted due to concern of environmental toxicity. For these reasons, the natural control of biofouling or environment-friendly methods is to be used. Such methods require a better understanding of the fouling community of cage netting, particularly how it interacts with the physical environment and aquaculture itself. It has been recently demonstrated that silicone coatings provide an effective non-toxic solution to reduce fouling on sea-cages and to increase the ease of fouling removal.

Fouling organisms of the cage can be controlled biologically to some extent by using grazer fish species within the culture fish. Grazing by wild fish and other predators could also contribute to the slower colonization rates outside the cages. The introduction of predatory fishes or sea stars could provide some amount of control on the growth of fouling organisms. *Cyprinus carpio* consume algae on nets and in the cage. Thus polyculture, when it is possible, may be a solution to limit fouling development in some sites.

Abrasion

Abrasion of the netting with fishes, with the rafts and frames as well as between inner and outer net in cases where double netting is provided are problems encountered. It is a common practice to have double netting. The outer one serving as a predator net, to protect the inner net with the fish stock.

In cases where the netting has a chance of rubbing with the frames or brackets, provision of a selvedge netting of same mesh size but of thicker twine would avoid the breakage of netting along the point of abrasion

Maintenance procedure

Maintenance of cages involves net changing, cleaning and mending.

Cage changing: The frequency of change depends on the mesh size of the cage and the season for fouling organisms which cause the cage to clog. As cage changing is time consuming and laborious, a mechanised net hauler may be considered for lifting out heavily fouled cages.

Cage cleaning: The nets should be cleaned regularly to prevent excessive fouling that may result in net breakage and heavy losses of fish. The smaller the mesh size, the heavier the rate of fouling. Nets of mesh size less than 2.5cm should be cleaned within 1 or 2 weeks of use whereas the larger size nets need to be cleaned in 30 to 90 days. Fouling organisms are removed by a high pressure water jet.

Cage drying: The cleaned net is checked for holes and repaired before it is used again. It can also be hung-up to dry and mend in position.

Cage mending: Net panels may get damaged or ropes may become weakened from frequent use. Panel and roped replacement or partial replacement with rejoining may be required, in such cases.

Due consideration need to be given for the design, construction and maintenance of the cage for the success of cage culture. Selection of suitable netting material, fixing of optimum mesh size and periodic maintenance of the net bag are the most important parameters to be taken into account. Focused research is needed on selection of netting materials, optimization of cage design and construction for different species and culture sites and on fouling control measures.

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Principles and practices of cage mooring

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Moorings are required to hold cages against the forces generated by wind, currents and waves and to allow the fish stocks and the cages and let the best chance of survival. In sheltered waters, requirements to moor a cage safely were minimal. This has changed dramatically with moves into coastal waters, and a potentially much higher wave climate. Mooring failures were common place in the early days of coastal farming, but a better understanding of the problems, and more sophisticated analysis has largely reduced these risks. Perhaps the most important point is to view the cage group, its nets and moorings, as a single system, whose components are mechanically linked. Their dynamic responses cannot be considered in isolation, each component affecting the other. Cage and mooring design is "site specific", and careful and combined choice of cage type, nets and most specifically moorings, has a considerable bearing on the ability of fish stocks to survive in major storms, on exposed sites.

Most moorings systems consist of lines and anchors that secure cages in a particular location. However, the moorings also influence the stress acting on cage structural members and the behavior of the cages in rough weather, and can affect production, profitability and staff safety. They are therefore an important - indeed, integral part of the cage system and should be carefully designed. Thus the collar, net and mooring components of a cage system should be designed together, although in practice the cages are usually chosen or built first with the mooring system being designed as an afterthought.

Mooring requirements should be determined by the design and type of the cages and the characteristics of the site. It would first be necessary to quantify the incident forces that are likely to act on the cage under the worst possible weather conditions, and then to evaluate the proportion of energy transferred to the mooring lines and anchors. Two types of analysis can be used: quasi static and dynamic response. The loadings transferred to mooring lines vary enormously depending on current and wave conditions, cage design and number of lines employed.

Mooring design for a specific cage system and site

Wind and current forces are proportional to the square of the velocity. Thus an increase in current from 1 knot to 2 knots will generate 4 times the drag on a rigid submerged body. Wave forces are much more difficult to compute, because the dynamic response of a system depends on so many factors. A change in the mooring system will change the internal loads on the cage system. This is a complex topic, but in general a mooring system should be designed not only for specific cages, but also for the expected site conditions of water depth, wind, waves and current.

Mooring components

Whichever type of mooring layout is employed, a number of elements need to be assembled together, correctly specified and installed, physically and operationally compatible with each other, and effective in use and maintenance. Key elements include the anchor or mooring unit on the seabed, the rising line, which connects the anchor to the surface system, and the surface or subsurface mooring grid. The major elements comprise several smaller sub-units – particularly links, shackles, droppers, safety lines, buoys, *etc.*, which in effect are integral in the complete system.

Anchor specifications

A range of different types is available, commonly from the shipping/fishing industry. Major options are usually between gravity or dead weight devices – mooring blocks or mass anchors, which rely primarily on their weight, and those which rely on their ability to wedge into the seabed substrate. Blocks are widely used because of their simplicity, their stability to tension in all directions, and their relative ease of positioning and relaying, but their efficiency is low. Gripping devices are much lighter and more efficient in the appropriate substrates – *e.g.*, muds and shingle mixes, but need to be properly tensioned; once bedded in they can also be difficult to reposition.

The simplest and cheapest type of marine anchor is the dead weight or block anchor, which typically consists of a bag of sand or stones or a block of concrete or scrap metal. The holding coefficient of the anchor (k) is defined as (R) the horizontal force divided by the mass of the anchor. The holding coefficient (k) depends upon the angle between the anchor and the cage and thus the ratio between water depth and line length and the nature of the substrate.

Block anchors have low holding power per unit-installed weight. The performance of a sand bag anchor is much poorer in mud. Concrete block anchors may be simply fabricated using wooden shuttering, tyres or any other convenient object as mould. Steel rods for strengthening and eyebolt for a mooring attachment are usually incorporated. Once fabricated, the blocks can be transported to the waters edge at low tide and floats attached, so that they can be floated to the required location at high tide. Once installed, they are difficult to recover.

There are numerous types of embedding anchor. The holding power of an embedding anchor is related to its frictional resistance in soil, and so is dependant on fluke area, soil penetration and the mechanical properties of the soil rather than simply the mass of the anchor.

Embedding anchors are very efficient, *i.e.* they have a high holding power to mass ratio. Under optimum conditions, they are 10-500 times as efficient as block anchors. They are more expensive than block anchors in terms of cost per unit holding power and have to be bedded in properly. The use of two anchors connected together gives greater holding power than the sum of independently moored anchors. There are numerous other type of anchor, combining the properties of block and embedding types, while others are designed for particular types of substrate.

Prior to choosing or installing anchors it is advisable to survey the sea bed. Anchors should be positioned first. The position of the anchors can be accurately established using a global positioning system or by taking bearings with respect to local. Easily visible land marks.

Rising line components

A range of materials and configurations may be used, the most common of which involves a chain section at the lower end of the line, a synthetic rope in the main upper length, and various elements of buoyancy or weighting to adjust the profile of the line, and its response geometry when subject to varying load. A range of different types and specifications may be available for chain and rope. Key issues concern weight and tensile strength, elasticity (length change with applied tension), stretching, dimensional wear, degradation. Float units need to be specified according to volume and shape, and to their resistance to deformation when submerged.

Mooring lines must perform two functions: they must withstand and transmit forces. The loads imposed on a cage mooring system are principally dynamic. It is important that mooring lines have a high breaking strength and can absorb much of the kinetic energy of rapidly changing force s, otherwise theses forces will be transmitted directly to the anchors. Natural fibre rope is not suitable as it is easily abraded and prone to rotting. Steel cable, although immensely strong, is expensive and heavy. Chain is extremely strong but again is heavy and is usually used in conjunction with synthetic fiber rope. Synthetic ropes of same diameter nylon and PES are considerably heavier than PP or PES. However, nylon is much stronger on a per unit weight or equivalent diameter basis than ropes fabricated from the other materials. Braided ropes are lighter than laid ropes and are generally weak. They also cost more and have few advantages other than they are easier and more pleasant to handle and do not kink. Although it can cost twice as much as PE or PP rope of equivalent strength, nylon has high extensibility and thus energy absorbing properties, an important factor in designing cage moorings.

Ropes should not be attached directly to either shore or sea anchors, but instead should be connected via a section of chain. The chain serves to increase the effectiveness of the mooring system, which directly act as an efficient type of anchor and improves the holding power of existing anchor by both reducing the angle between the mooring line and anchor and by increasing energy absorbing properties of the mooring line.

Moreover, a section of chain is necessary at the anchor since it is much resistant than synthetic fibre rope to the prevailing high abrasion forces. There are several types of chains are available. Wrought iron is very variable in quality; the best has excellent corrosion resistance while the poorer grades are inferior in all respects. Mild steel chain, with low carbon and manganese contents has been widely recommended for cage anchorages. A fairly heavy grade of chain is recommended.

The total length of the mooring line should be at least three times the maximum depth of water at the site and where the rope joins the chain, a galvanized heavy duty thimble should be spliced into the rope and a galvanized shackle of the appropriate size should be used to connect the chain and tot eh rope.

An alternative mooring line composed mainly of chain is occasionally employed. Typically 12-25mm chain, two or three times the maximum depth of water in length is connected from the anchor to a float positioned 10m or so from the cage and a section of rope –PES or nylon-used to link the floats to the cages. The buoy minimizes the vertical loading on the cages and must be sufficiently large to support the mass of the chain in the water and to resist the vertical forces imposed by the cages on the mooring system. A single float per mooring line tends to be used, although reductions in line tension from using a series of floats with the same floatation capacity as a single float. Under shock loads, the chain/buoy acts as a spring absorbing much of the energy that would otherwise be transmitted to the anchor.

Two types of mooring systems be used: multiple and single point. The former is more common and involves securing the cages in one particular orientation while with the latter the cage are moored from one point only, allowing them to move in complete circle. Single point moorings tend to be used with rigid collar designs in sheltered sites. They use less chain and cable than multiple point moorings and because they adopt a position of least resistance to the prevailing wind, wave and current forces, both inter cage forces and torsion forces at linkages are reduced. Single point mooring systems also reduce the enormous net deformation seen in conventional mooring systems and have been used with successes to moor large offshore cages. Cages moored from a single point also distributes wastes over considerably larger areas than those secured by a multiple point system.

The orientation of cages with multiple moorings depends upon the nature of the site and upon the type and group configuration of the cages. If particularly exposed or if currents are strong, then it may be best to secure cages in the position of least resistance to the prevailing wind and current forces. Where a site is sheltered and water circulation is poor, it may be better to moor cages so that water exchange is maximized. However, there may be restrictions on mooring orientation imposed by the site size or by suitability of mooring grounds.

The number of mooring lines used determines the distribution of forces to the anchors. Most methods of mooring involve the use of ropes and chain to link the cage or cage group to anchors or pegs secured to the sea bed. The mooring line is often termed as a 'riser'. Although this is most common system there are alternatives. Some cages may use a submerged rope or cable based mooring grid, to which cages may be attached temporarily using near horizontal lines. One further alternative is to drive long posts into substrate and to attach cage directly either with ropes or with metal hoops or tyres that permit some vertical tidal and wave induced movement. In theory the number and dimensions of posts required and the depth to which they must be buried could be computed from the estimates of the forces acting on the cage system and data on the soil characteristics, but in practices it is determined by experience. Although sometimes employed in sheltered and shallow inland and coastal sites with suitable substrates, this method of mooring is not widely used.

There are a variety of methods of using single and multiple point moorings. one or two heavy ground chains can be laid which connects the cages to the anchors via mooring lines. Alternatively mooring lines can be run directly from the cages to the anchors. Points of stress are formed where mooring lines are secured to the cages and so it is important that they are secured at a number of places. Joints, where stress accumulate or are transferred from one structural member to another, are frequently used. Anchors are deployed to resist the principal directions of force and sometimes may be used installed on shore as well as at sea. Mooring lines must be secured to cage collars via attachment points able to withstand the forces generated. Structural members should be used and where abrasion is expected the line should be protected by encasing in plastic pipe.

Installation methods

The installation of mooring systems is an important aspect of the overall development of a cage site, and requires to be planned with care.

(i) Working base: a suitable and secure area for storing and laying out the mooring components needs to be identified – ideally a level, surfaced area.

(ii) Workboat or mooring vessel: capable of moving and positioning the mooring components and operating in the expected site conditions

(iii) Cranes: dockside and on mooring vessels – capable of lifting and moving the mooring elements safely at the required horizontal reach.

(iv) Access: – for materials to be taken to the assembly areas, for mooring components to be taken safely to the intended cage site.

(iv) Marking out: key locations in the mooring site can be marked out on a hydrographic chart, checked on site with GPS or conventional optical surveys; local transect markers can be identified, and temporary positions marked with light lines and floats

(v) Making up moorings: the mooring lines and grids need to be adjusted to length and assembled to form the appropriate sub-components, which would then be finally linked together on site once the anchors are laid. Primary work can most easily be done on shore, using temporary measure lines or markers to help lay off the line lengths. Further adjustments can be done at sea, and all components and connections given a final check before installation

(vi) Laying anchors and risers: if blocks are used, these can be set at the intended site, using positioning co-ordinates to define the location. For embedding anchors, these should be dropped a suitable distance outwards (*i.e.*, opposite the direction of tension) from the place of intended location, and tensioned inwards to their final position. Laying of moorings and lines should be done carefully, taking particular care not to foul anchors with riser line, to tangle or snag the line, or to endanger staff.

(ix) Tensioning the rising lines: these need to be finally adjusted to ensure that the cage and/or mooring assembly is correctly and evenly tensioned around its axes.

(x) Diver swim of rising lines: finally, it is very important to check the whole system visually – to ensure that blocks or anchors are cleanly placed and/or embedded, that lines are lying properly and are not kinked or tangled, and that connections are sound.

Mooring maintenance

Cage moorings are a dynamic system, which must respond to motion, under load, every minute of the years it is installed. Maintenance is critical, to ensure that components are physically sound and that linkages are secure. Critical dimensions of items subject to wear – chain links, brackets, shackles, splicing eyes, need to be checked periodically, bolts and shackle pins need to be tightened, and riser lines may need to be adjusted.

With a rigorous and effective system of maintenance of both cages and moorings, with clearly defined parameters for replacement or repair, a well designed and installed system should be capable of reliable and secure operation.

Mooring systems must be checked at regular intervals and fouling removed from buoys and mooring lines. it is essential that any mooring inspection assesses component strength to see if it deviates significantly from design strength and that it should also assess likely deterioration in the interval to the next inspection.

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Taxonomy, identification and biology of Seabass (*Lates calcarifer*)

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Introduction

Lates calcarifer (Bloch), commonly known as giant sea perch or Asian seabass, is an economically important food fish in the tropical and subtropical regions in the Asia –Pacific. They are medium to large-sized bottom-living fishes occurring in coastal seas, estuaries and lagoons in depths between 10 and 50m. They are highly esteemed food and sport fishes taken mainly by artisanal fishermen. Because of its relatively high market value, it has become an attractive commodity of both large to small-scale aquaculture enterprises. It is important as a commercial and subsistence food fish but also is a game fish. The most important commercial fish of Australia, and the most sought after game fish, generates millions of dollars per year in revenue for the sport fishing. *Lates calcarifer*, known as seabass in Asia and barramundi in Australia, is a euryhaline member of the family Centropomidae that is widely distributed in the Indo-West Pacific region from the Arabian Gulf to China, Taiwan Province of China, Papua New Guinea and northern Australia. Aquaculture of this species commenced in the 1970s in Thailand, and rapidly spread throughout much of Southeast Asia.

Among the attributes that make seabass an ideal candidate for aquaculture are:

It is a relatively hardy species that tolerates crowding and has wide physiological tolerances. The high fecundity of female fish provides plenty of material for hatchery production of seed. Hatchery production of seed is relatively simple. Seabass feed well on pelleted diets, and juveniles are easy to wean to pellets. Seabass grow rapidly, reaching a harvestable size (350 g – 3 kg) in six months to two years.

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

Australia is experiencing the development of large-scale seabass farms, where seabass farming is undertaken outside the tropics and recirculation production systems are often used (*e.g.* in southern Australia and in the north-eastern United States of America). Seabass has been introduced for aquaculture purposes to Iran, Guam, French Polynesia, the United States of America (Hawaii, Massachusetts) and Israel.

Taxonomy

Phylum	Chordata
Sub-phylum	Vertebrata
Class	Pisces
Sub-class	Teleostomi
Order	Percomorphi
Family	Centropomidae
Genus	Lates
Species	*Lates calcarifer* (Bloch)

The above is an accepted taxonomic classification of seabass or giant perch. Seabass has been placed under several families by various authors in the past (*e.g.* the grouper family, Serranidae and family Latidae, *etc.*) However, Centropomidae is the commonly accepted family name of this species, and the recognized generic name is *Lates*. Other names such as *Perca, Pseudolates, Holocentrus, Coins, Plectropoma, Latris*, and *Pleotopomus* were also given by various authors who collected the fish specimens from different areas. Bloch (Schneider 1801) stated that *Lates calcarifer* occured in Japan Sea but named it as *Holocentrus calcarifer.*

English: Asian seabass, Barramundi perch; French: Brochet de mer.

The common local names of this species are listed below:

English	:	Giant perch, white seabass, silver seaperch, giant perch, palmer, cock-up seabass
India	:	Begti, bekti, dangara, voliji, fitadar, todah
East Bengal	:	Kora, baor
Sri Lanka	:	Modha koliya, keduwa
Thailand	:	Pla kapong kao, pla kapong
Malaysia	:	Saikap, kakap
North Borneo	:	Ikan, salung-sung
Vietnam	:	Ca-chem, cavuot
Kampuchea	:	Tvey spong
Philippines	:	Kakap, apahap, bulgan, salongsong, katuyot, matang pusa
Indonesia	:	Kakap, pelak, petcham, telap
Australia and Papua New Guinea	:	Barramundi

Morphology and distinctive characters

\Body elongated, compressed, with deep caudal peduncle. Body large, elongate and stout, with pronounced concave dorsal profile in head and a prominent snout; concave dorsal profile becoming convex in front of dorsal fin. Mouth is large, slightly oblique, upper jaw reaching to behind eye; teeth villiform, no canine teeth present. Lower edge of pre-operculum is with strong spine; operculum with a small spine and with a serrated flap above original of lateral line. Dorsal fin with 7 to 9 spines and 10 to 11 soft rays; a very deep notch almost dividing spiny from soft part of fin; pectoral fin short and rounded; several short, strong serrations above its base; dorsal and anal fins both have scaly sheath. Anal fin round, with three spines and 7–8 soft rays; caudal fin rounded. Scale large ctenoid (rough to touch). Colour: two phases, either olive brown above with silver sides and belly in marine environment or golden brown in freshwater environment. In adult, it is usually blue-green or greyish above and silver below. Fins are blackish or dusky brown. Juveniles have mottled pattern of brown with three white stripes on head and nape, and white blotches irregularly placed on back. Eyes are bright pink, glowing at night.

Distribution

Geographic distribution

Seabass is widely distributed in tropical and sub-tropical areas of the Western and Central Pacific and Indian Ocean, between longitude 50°E - 160°W latitude 24°N – 25°S (Fig. 1). It occurs throughout the northern part of Asia, southward to Queensland (Australia), westward to East Africa. Found in coastal waters, estuaries and lagoons. Usually occurs at depths of 10 to 40m.

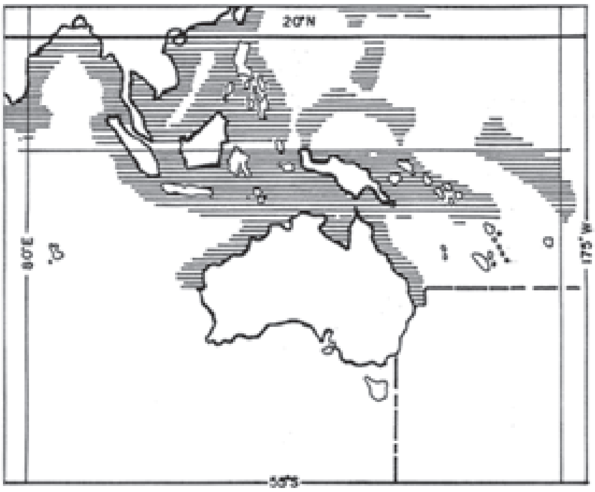

Fig. 1 Geographic distribution of Lates calcarifer (FAO, 1974)

Ecological distribution

Seabass is a euryhaline and catadromous species; inhabit freshwater, brackish and marine habitats including streams, lakes, billabongs, estuaries and coastal waters. Sexually mature fish are found in the river mouths, lakes or lagoons where the salinity and depth range between 30–32 ppt and 10–15m, respectively. The newly-hatched larvae (15–20 days old or 0.4–0.7cm) are distributed along the coastline of brackishwater estuaries while the 1-cm size larvae can be found in freshwater bodies *e.g.* rice fields, lakes, *etc.* (Bhatia and Kungvankij, 1971). Under natural condition, seabass grows in fresh water and migrates to more saline water for spawning. Adults and juveniles tend to be solitary, patrol home ranges near structure, and may be territorial. Migration is seasonal.

Life history

Seabass spends most of its growing period (2–3 years) in freshwater bodies such as rivers and lakes which are connected to the sea. It has a rapid growth rate, often attaining a size of 3–5 kg within 2–3 years. Adult fish (3–4 years) migrate towards the mouth of the river from inland waters into the sea where the salinity ranges between 30–32 ppt for gonadal maturation and subsequent spawning. The fish spawns according to the lunar cycle (usually at the onset of the new moon or the full moon) during late evening (1800–2000 hours) usually in synchrony with the incoming tide. This allows the eggs and the hatchlings to drift into estuaries. Here, larval development takes place after which they migrate further upstream to grow. At present, it is not known whether the spent fish migrates upstream or spends the rest of its life in the marine environment.

Smith (1965) noted that some fish spend their whole life in freshwater environment where they grow to a length of 65 cm and with 19.8 kg body weight. The gonads of such fish are usually undeveloped. In the marine environment, seabass attaining a length of 1.7 m have been recorded in the Indo-Australian region (Weber and Beaufort 1936).

Eggs are pelagic, hatch within 24 hours, and the larvae grow quickly as they move into mangrove areas, mudflats, and floodplain lagoons. Juveniles move into coastal waters after one year, and then migrate upstream where adults reside for three to four years. Populations landlocked by dams migrate to the dam face, but do not spawn. It is reared extensively by aquaculture as food or for game fish-stocking programs. Catadromous migration is observed, where the fish migrates downstream to shallow mudflats in estuaries during the wet season.

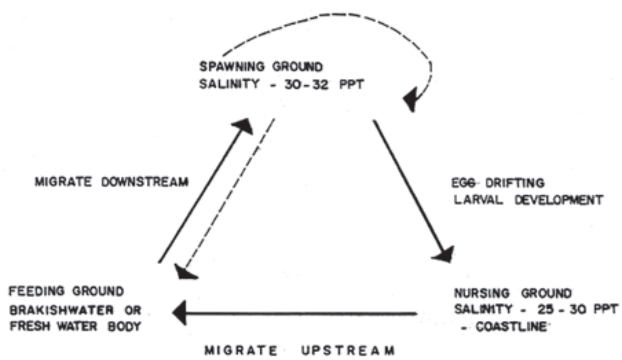

Fig. 2 Migration pattern of Lates calcarifer Bloch

Feeding habits

Seabass or barramundi are opportunistic predators; crustaceans and fish predominate in the diet of adults. Although the adult seabass is regarded as a voracious carnivore, juveniles are omnivores. The fish is skilled at stalking or ambushing prey. Analysis of stomach content of wild specimens (1–10 cm) show that about 20% consists plankton, primarily diatom and algae and the rest are made up to small shrimp, fish, *etc.* (Kungvankij 1971). Fish of more than 20 cm, the stomach content consists of 100% animal prey: 70% crustaceans (such as shrimp and small crab) and 30% small fishes. The fish species found in the guts at this stage are mainly slipmouths or pony fish (*Leiognatus* sp.) and mullets (*Mugil* sp).

Sex determination

Identification of the sexes is difficult except during the spawning season. There are some dimorphic characters that are indicative of sex (Fig. 3).

- Snout of the male fish can be slightly curved while that of the female is straight.
- The male has a more slender body than the female.
- Weight of the female is heavier than males of the same size.
- The scales near the cloaca of the males are thicker than the female during the spawning season.
- During the spawning season, abdomen of the female is relatively more bulging than the males.

Sexual maturity

In the early life stages (1.5–2.5 kg body weight) majority of the seabass appear to be male but when they attain a body weight of 4–6 kg majority become female. After culture period of 3–4 years, however, in the same age group of seabass both sexes can be found and identified as mentioned above. In a fully mature female, the diameter of the oocysts usually ranges from 0.4 to 0.5 mm.

Fecundity and spawning

Females are larger than males, are highly fecund, and may be courted by one or more males at the same time. The fecundity of seabass is related to the size and weight of the fish Spawning occurs between September and March, with peaks in November to December and again in February to March. Spawning seasonality varies within the range of this species. Barramundi in northern Australia spawn between September and March, with latitudinal variation in spawning season, presumably in response to varying water temperatures. In the Philippines barramundi spawn from late June to late October, while in Thailand spawning is associated with the monsoon season, with two peaks during the northeast monsoon (August – October) and the southwest monsoon (February – June).

Fig. 3 Photograph of adult male and female seabass

Spawning occurs near river mouths, in the lower reaches of estuaries, or around coastal headlands. Barramundi spawn after the full and new moons during the spawning season, and spawning activity is usually associated with incoming tides that apparently assist transport of eggs and larvae into the estuary.

Seabass being highly fecund; a single female (120 cm TL) may produce 30–40 million eggs. Consequently, only small numbers of broodstock are necessary to provide adequate numbers of larvae for large-scale hatchery production.

Table 1 Relationship between size of fish and number of eggs from the gonads of seabass (*Lates calcarifer* Bloch) (After Wongsomnuk and Maneewongsa, 1976)

Total length(cm)	Weight	No. of fish	Fecundity (million eggs)	
			Range	Average
70 – 75	5.5	3	2.7 – 3.3	3.1
76 – 80	8.1	5	2.1 – 3.8	3.2
81 – 85	9.1	4	5.8 – 8.1	7.2
86 – 90	10.5	3	7.9 – 8.3	8.1
91 – 95	11.0	3	4.8 – 7.1	5.9

Based on studies of spawning activity under tank conditions, mature male and female fish separate from the school and cease feeding about a week prior to spawning. As the female attains full maturity, there is an increase in play activity with the male. The ripe male and female, then swim together more frequently near the water surface, as spawning time approaches. The fish spawns repeatedly in batches for 7 days. Spawning occurs during late evening (1800- 2200 hours).

Embryonic development

First cleavage occurs 35 minutes after fertilization. Cell division continues every 15 to 25 minutes and the egg develop to the multi-celled stage within 3 hours. Its development passes through the usual stages: blastula, gastrula, neurola and embryonic stages. Embryonic hear starts to function in about 15 hours and hatching takes place about 18 hours after fertilization at temperatures of 28–30°C and salinities of 30–32 ppt (Table 2, Fig 4a & b).

Larvae

Newly-hatched larvae have total length ranging from 1.21 to 1.65 mm averaging 1.49 mm. The average yolk sac length is 0.86 mm. One oil globule is located at the anterior part of the yolk sac which causes the hatchling to float almost vertically or about 45° from its usual horizontal position. Initial pigmentation is not uniform; the eyes, digestive tract, cloaca and caudal fin are transparent. Three days after hatching, most of the yolk sac is absorbed and the oil globule diminishes to a negligible size. At this stage, the mouth opens and the jaw begins to move as the larva starts to feed.

Larvae recruit into estuarine nursery swamps where they remain for several months before they move out into the freshwater reaches of coastal rivers and creeks. Juveniles remain in freshwater habitats until they are three–four years of age (60–70 cm TL) when they reach sexual maturity as males, and then move downstream during the breeding season to participate in spawning.

Because they are euryhaline, they can be cultured in a range of salinities, from fresh to seawater. When they are six–eight years old (85–100 cm TL), seabass change sex to female and remain female for the rest of their lives. Sex change in Asian populations of this species is less well defined and primary females are common.

Although seabass have been recorded as undertaking extensive movements between river systems, most of them remain in their original river system and move only short distances. This limited exchange of individuals between river systems is one factor that has contributed to the development of genetically distinct groups of barramundi in northern Australia, where there are six recognised genetic.

Table 2 Embryonic development of seabass eggs (Kungvankij 1981).

Embryonic stage	Hours & minutes after spawning	
	Hours	Minutes
Fertilization	-	5
2-cell	-	35
4-cell	-	55
8-cell	1	10
16-cell	1	30
32-cell	1	50
64-cell	2	20
122-cell	3	-
Blastula stage	5	3
Gastrula stage	7	00
Neurola stage	9	10
Embryonic stage	11	50
Heart functioning	15	30
Hatch out	18	-

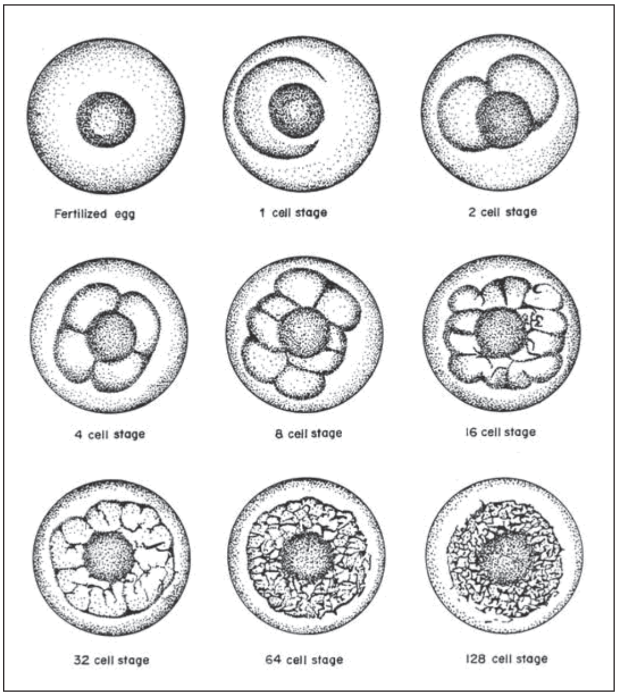

Fig 4a Development of egg

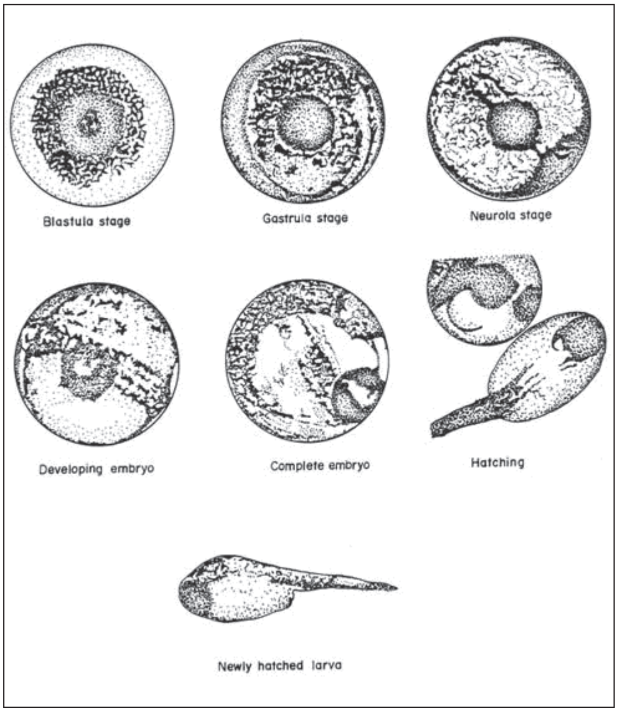

Fig 4b Development of egg

There are at least two pigmentation stages in seabass larvae. At 10–12 days after hatching, the pigmentation of larvae appears dark gray or black. The second stage occurs between 25–30 days old where the larvae develop into fry. In this stage, the pigmentation changes to a silvery-coloration.

It has been observed that only healthy fry of this stage (20–30 days) swim actively. They are always lighter in color. Unhealthy post larvae have dark or black body coloration.

Growth

The growth rate of seabass follows the normal sigmoid curve. It is slow during the initial stages but becomes more rapid when the fish attains 20–30 gm (Table 3). It slows down again when the fish is about 4 kg in weight.

Table 3 Age, average body length and weight of seabass under tank conditions

Age(days)	Average length(mm)	Average body weight
Fertilized eggs	0.91	
0	1.49	
1	2.20	
7	3.61	
14	4.35	
20	9.45	
30	13.12	0.1
40	17.36	0.5
50	28.92	

Conservation status

Not listed by the IUCN, but has been threatened by habitat destruction and over fishing.

Nursery rearing of seabass fry and importance of grading and seed transportation

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The Asian seabass (*Lates calcarifer*) is an important food fish and a potential aquaculture species in tropical countries. It exhibits catadromous habits within its areas of distribution. It is an advantageous culture species because after early larval rearing in seawater, it can be cultured in all levels of salinity, from fresh to seawater, and in a variety of culture systems from open ponds and cages to flow-through and closed recirculation systems. In addition, this species produces large number of eggs that can be reared intensively on fresh and pelleted feeds, and can reach a market size of 350 to 700 g in one year or less periods under optimum culture conditions.

Seabass spawn naturally in captivity and the fertilized eggs take 12 to 15 hours for hatching. The spherical eggs range from 0.74 to 0.80 cm in diameter with a single oil globule from 0.20–0.28 mm in diameter (Maneewong and Watanabe, 1984). The mouth opens when the larvae get to about three days old and the yolk has been almost completely absorbed. This is a sign that the fry can start to feed.

Seabass larvae and juveniles

Seabass is a carnivorous voracious feeder; and it is highly cannibalistic in the earlier stages like larvae and juveniles. Food and feeding are two of the most important factors that affect the survival rate of seabass larvae as well as juveniles. In case of inadequate feeding times not only the lack of food but also the cannibalism will work together and the survival rate will be lower in double effects. The larvae or juveniles cannot survive if there is inadequate supply of food, which comprises various live organisms, and that again varies with the development of the larvae. Most of the food that seabass larvae feed on is composed of live zooplankton. The larvae first begin to feed on rotifer. It is reported that other kinds of food have also been tried with the early larvae but without success. The supply of live zooplankton is expensive and sometimes causes problems because zooplankton culture needs time, facilities and skills. Further, the different kinds of live food required must be prepared in time to satisfy the need of the fast-growing larvae. To maintain a high survival rate, the feeding schedule for the larvae must be closely adhered to.

Nursery Management

Tank

Seabass fry and fingerlings should be reared in concrete tanks up to the size 2.5 cm or 1 inch. After that, they can be transferred for rearing in nylon net cages until they attain 25 cm or 10 inches in about 2 to 3 months of culture period. The rearing tank should be cleaned up every time before using. The rates of water replacement in the rearing tanks depend on feeding period of each age stage. In the period of rotifer feeding to prevent the loss of rotifer through the outlet, approximately 10–20 percent of the water in the rearing tank is drained out only for the replacement of rotifer supply each day. During *Artemia* feeding period, approximately 50 percent of water is changed while almost complete change is made during trash fish feeding period. The sediment of dead organisms, larvae or leftover food is siphoned out everyday. The management of seabass nursery is shown in Fig.1.

(iii) the replacement may be gradual, occurring over several days, as in the culture of red sea bream and Japanese flounder. On 25^{th} day, when the fry measures @1.0 cm, it should be transferred to nursery tanks in the hatchery or nursery hapas at the farm site for weaning. Though seabass prefers live fish food it could be weaned to trash fish within 5-7 days. Fry are stocked @ 1000 nos./m^3 in 4-5 tonne capacity tanks. The cooked and minced fish meat, made into small pieces of 1.5- 2.5 mm, should be given as feed *ad libitum* during the nursery rearing. Grading (removal of shooter fish) should be done on alternative days to reduce cannibalism.

1.__________3.__________10.__________14.__________20.__________25.__________30.__________40

2.__green water and other algae__

_________Rotifer _______

__________________Artemia_______

______Daphnia__________

_______Trash fish_________

3.——RCW——10-20% change———I——————50%————————I——80%—————

4. ___________1^{st} grading____I_________2^{nd} grading___I______Weeky once_______

Fig. 1. Management method for seabass nursery tank within the first 40-day period 1 Time duration 2 Feed 3 Water change 4 Grading.

Weaning

The inclusion of artificial food in the diet of marine fish larvae is a critical stage in intensive larval rearing. The process of changing diet of the fish larvae from the live feeds to the artificial diets or *vise versa* is called weaning. Weaning reduces the dependence on live feeds, and therefore reduces hatchery running costs. Person-Le Ruyet (1991) described three weaning strategies which have been applied to different species of marine fish larvae, with different levels of success; (i) weaning at first feeding has been achieved with plaice and sole with lower survival than achieved with live feeds; (ii) larvae may be reared for some time on live feed, which is then replaced abruptly with artificial feed; this strategy is used for European seabass or

Importance of grading and grading techniques

Cannibalistic behaviour of seabass fry can be observed after the fry completes metamorphosis, when they are about 15 days old (15 mm in total length). To maintain a uniform size and minimize the mortality of the fry, grading of fry to size groups at regular and frequent intervals must be done. Due to cannibalistic nature of the fish, size selection or grading or sorting of the larvae is of prime importance based on the size of the fish. The first sorting should start at the second week since during this period; the bigger fish can eat the smaller ones. After the first size grading at around 12-15 days old, size grading should be done every 3-5 days (Maneswongsa, 1986; Ruangpanit, 1988). The easiest way of sorting is to use screen with various mesh size so that the various sizes of fish can be separated easily. Another material usually used for grading consists of plastic containers punched at the bottom with holes of 2, 3.5, 5, 6 and 7 mm in diameter. Fish are placed in the plastic containers which are floated in the newly prepared larvae nursing tank. The small fish can pass through the hole to the new tank. The remaining fish in the plastic containers are transferred into another tank and likewise graded with the use of a plastic container with larger holes. Different types of graders fixed as well as adjustable types are now available in the international market and a few types in the Indian markets.

Stocking same size fish will reduce the rate of cannibalism, thus the survival rate can be increased and the growth rate of the fish could also be faster and more uniform. Grading is also important in the fact that these fishes are voracious carnivorous feeders and the competition for food is very high during the feeding time. If the number of fishes in the tanks as well as in the hapa are high, the competition again increases and only the fittest will get the food. Again these are column feeder and usually they never feed on the left over food in the bottom. So all of them will have to get the food and eat in the same time, this will not be possible in the tanks or hapa. Here the weak ones cannot grasp food as efficient as the healthier ones and hence they become more weak when compared to the eating ones that grow further in size.

Growth and care of larvae as they develop to fry and Juveniles

When the fry are 50 days old or 1.0-2.0 cm length they are transferred to another tank (Ruangpanit et *al.,* 1988). The ground fish meat can be fed at age 45 days with *Artemia* nauplii. Filtered sea water is totally changed and supplied every day. The semi moist compound diet is given three times a day. The juveniles can also rear in the net cages in the open waters. They can be moved from the rearing tanks for culture in net cages of different size and shape according to the convenience and availability of the water bodies. The net cages usually uses are 2x1x1.5 m and they are usually set in open waters one day before stocking to remove the contaminants if any. Stock of 2,000–3,000 fry are raised to the fingerling size in these cages.

Survival Rate

The system of culture outlined above gives about 85 percent hatching rate and a survival rate of 1–7 days old larvae of 30 percent. For 8–15 days old larvae the survival is 80 percent, after which they can be maintained indefinitely with negligible mortality (Table 1).

Table 1 Survival rates of seabass larvae at various ages under normal stocking rates in tanks

Age (days)	No. of larvae* per liter	Survival Rate(%)
1–7	30–40	37.2
8–15	15–20	80.9
16–23	5–10	70.0
24–30	2–5	85.3

** Normal stocking density used in nursery tanks.*

Salinity acclimatization

It is a euryhaline species except in its early larval stages. These can be easily acclimatized from one salinity to any other salinity *i.e.* from sea water to fresh water within short period of time without any mortality. Thus, it is an advantageous culture as it can be cultured in all levels of salinity, from fresh water to sea water, and in a variety of culture systems from open ponds and cages to flow-through and closed recirculation systems. It can easily adjust to change of 5 – 10 ppm at a time. Therefore in a day it can be changed from sea water to fresh water and vise versa.

Collection and conditioning of fry before transport

Fry are collected from the rearing tanks and placed in smaller receptacles. Fry are treated with 5 ppm of acriflavine solution or 0.5 ppm of copper sulfate solution for 5–10 minutes. There should be no feeding within 1–2 hours before packing.

Packing

Plastic bags of 40 × 60 cm of proper gauge are filled with 6–7 litres of fresh seawater and saturated with oxygen; 10–12 litres of oxygen gas are used for packing. The amount of transportable fry depends on size of fry, water temperature in plastic bags and duration of travel and handling from source of fry to its destination.

Transport

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

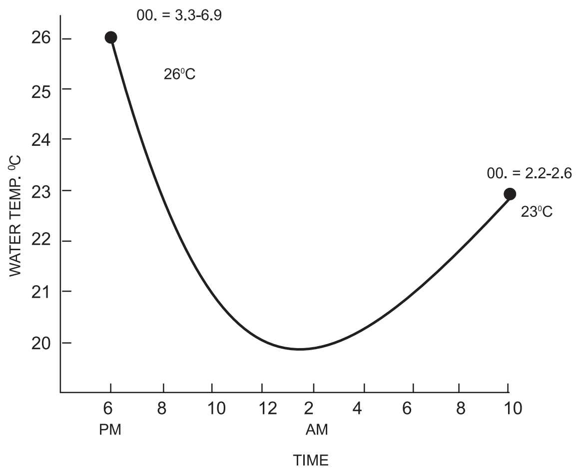

Fig. 2 shows the observed fluctuation in temperature of the water in the plastic bags during transport. It was also observed that the dissolved oxygen starting initially at 5.3 to 5.0 ppm will drop to 2.3-2.6 ppm at destination.

Pond nursery

Nursery rearing of seabass fry in ponds in hapa to the size of stocking is essential before release into the cages. Nursery ponds may range in size from 500-2000 m². A water depth of 1-1.5 m is desirable. Rearing of juveniles in hapa in the earthen ponds is easy and economical when it compared with that of the tank systems. This method is advantageous than other methods since it can be easily managed and installation of rearing facility requires less space and capital investment. The infrastructural facilities including the man power is very less compared to the tank systems. The huge amount of water exchange can be avoided if it is reared in hapa in the ponds. It is easy to maintain the water quality parameters in the ponds if it is having easy approach to the natural water bodies. If the ponds are provided with the water exchange facility it is well and good. The ponds with tidal fled systems are very good as the water can be entered and removed easily without any power consumption. Again the number of the hapa can be extended to any scale depending on the necessity and the capability of the farmer. It can be maintained in a corner of the grow-out pond or near the grow-out cages itself. The water flow in the cage site washes away the metabolites and excess uneaten feed.

Pond preparation

The pond is made ready three weeks ahead of the date on which the fry is expected. Adequate provision of water inlet and outlet should be provided. A slope towards the drainage side is preferred for the easy removal of the waste materials for keeping good water quality in and around the hapa. Both sluices/ the inlet and outlet channels should be guarded by 1 mm mesh nets to prevent the entry of unwanted fishes as well as escape of the fry in the case of some hapa damage. The nursery pond should be free from predators. Predators are killed by *mahua* oilcake (which is toxic for three weeks), which then acts as a good fertilizer, giving a rich crop of zooplankton which is good for the juveniles in rearing ponds. If there are no weeds, to kill predators and competitors quickly, just add 100 kg of urea followed 24 hours later by 200 kg of fresh bleaching powder (which is toxic for only a week) for a 1-ha area of a 1-m deep pond. Fish killed in this way is edible. A week after treatment with bleaching powder, add fresh cow dung (2,500 kg/ha) or a mixture of cow dung (2,500 kg/ha) and poultry manure (1,250 kg/ha). If *mahua* oilcake is used, fertilizer need not be added for the first 15 days. The pond should be stocked as soon as it is ready and as early in the season as possible to get fry, which makes the best use of the available water and the high temperatures.

In prepared nursery ponds, fry of 2.5 to 4.0 cm size can be stocked @ 1500-2000 nos/hapa of 2 x 2 x 1 m. The most convenient cage design is a rectangular cage made of synthetic netting attached to wooden, GI pipe or bamboo frames. It is either a) kept afloat by styrofoam, plastic carbuoy or b) stationary by fastening to a wooden or bamboo pole at each corner. The size of cage varies from 0.9 × 2.0 m and a depth of 0.9 m to 1.0 × 2.0 meters and a depth of 1.0 meter (Figure 1). The mesh size of the nylon net is 1.0 mm. The mesh size of the hapa should be appropriate with the size of the fishes as well as it should allow the water movement. Water exchange to the extent of 30% is required daily to the pond. Fry must be fed with supplementary feed of chopped and ground fish (4-6 mm size) @ 100% of the body weight, thrice a day, in the first week. The feeding rate is gradually reduced to 60% and 40% during second and third week respectively. The minced fish meat, made into small pieces of 1.5-2.5 mm, should be given as feed *ad libitum* during the nursery rearing. Grading (removal of shooter fish) should be done on alternative days to reduce cannibalism. At this stage the nets of the hapa should be cleaned for 3 – 4 days as it gets clogged with algal materials which reduces the water flow and the water quality within the hapa. The expected survival rate would be 80-86% with an average size of 5 to 7.5g in 30-35 days of rearing in the hapa. However, after a month of nursing, they can be transferred to cages with nylon net with mesh size of 0.5 cm. Stocking is done separately for each size group. This would minimize the losses from cannibalism. Fingerlings of 2.5–5.0 cms should be fed with ground trash fish at 8–10 percent of body weight daily or about 4 to 5 times a day. After that, they can be fed with finely chopped trash fish.

The mesh size as well as the size of the hapa can be changed as the fishes grow to bigger sizes which will increase the growth and at the same time reduces the clogging and the cleaning due to it. This would allow water to pass through the cages more freely. Nursery cage size may range from 3 m (3x1x1 m) to 10 m (5 x 2 x 1 m) with a mesh size of 10 mm. Cages/ hapa should be checked and cleaned regularly. The fry on reaching a size of 25 -40 g at the end of another rearing period of 30-45 days can be stocked in the open sea cages for the grow-out system. Usually a survival rate ranging from 50-70% could be obtained. The net cage should be checked daily to ensure that it is not damaged by crabs or clogged with fouling organisms. The cage should be cleaned every other day by soft brushing in order to allow water circulation in the cage.The survival rate for the nursery period would be 50 to 80 percent. This would depend on feeding, aquatic environmental conditions, and the expertise of the fish farmers.

Trash fish is the main feed for seabass culture. Trash fish should be fresh and clean. Trash fish used are sardines and other small marine fish. The trash fish should be chopped and fed thrice a day, in the early morning, afternoon and evening. The size must be suitable for the size of the mouth of the fish. The farmers should give the feed slowly and watch the fish. Feeding should be stopped when the fish no longer come up to the surface; it shows that the amount of feed is enough for them.

Diseases

If hygienic conditions are maintained, the juveniles are generally resistant to diseases. However, since the larvae are stocked in the tank for a long period, sometimes they show their abnormal swimming character, stop feeding, and turn black. These are signs of disease or poor health so that if these occur, they should be treated with 1:2,000 parts formalin solution for 10–15 minutes for 2–3 days continuously. It is commonly known that the seabass fry when collected from natural areas are big enough so that they can be suitable for stocking grow out ponds and cages. As now it is able to spawn the fish and grow the larvae and juveniles under controlled conditions, better knowledge is available on their growth. It is also successfully completed the nursing of the seabass larvae and juveniles in controlled conditions with relatively high survival rates without much health problems at present.

Collection, conditioning and transport of juveniles to the grow-out systems

Fry are collected from the rearing tanks and placed in fiber glass tanks in the same salinity. There should be no feeding within 1–2 hours before packing. If the salinity of grow out is different the fishes should be acclimatized to the salinity of grow-out first before transportation. As the fishes are now grown to a bigger size, it is better to transport them in the bigger containers like syntax tanks with aeration in good quality waters.

Important management measures in cage culture

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To get the maximum benefit out of the cultured system, given the restrictions imposed by the site, species or type of feed used, the stock must be kept in conditions which minimise losses and promote good growth and finally optimum production. It is to be considered first that the cages must be of a reasonable size that makes management by an individual or small group easy.

The major factors to be taken care in cage management are:

- Stocking the candidate species at optimum density appropriate to the site and rearing conditions
- Feeding the fish in the most cost effective manner aimed at maximum production
- Ensuring the best possible water quality within the cages
- Maintaining cages, moorings, anchors, nets and related accessories
- Regular monitoring of the cultured species by sampling, for details on health conditions, removal of dead fishes, and treatment of infected fish

Stress reduction to the fish

Stress can be defined as any physical, chemical or environmental stimulus which tends to disrupt normal well being of an animal. The processes of capture, handling, loading and transport are highly stressful to fish, resulting not only in physical damage, but also in changes in blood chemistry, increased oxygen consumption, osmoregulatory problems, and increased susceptibility to disease. Under stressful conditions, fish must expend more energy to maintain homeostasis (tendency of an organism or cell to maintain internal equilibrium by adjusting its physiological processes) and less energy to combat disease. Aquatic organisms are fundamentally different from terrestrial animals: they are immersed in their environment and cannot go somewhere else. Some disease agents are almost always present in the water (ubiquitous). These opportunistic pathogens will invade fish when they become stressed. Thus, it is essential to reduce stress factors in cultured fish.

Common measures to reduce stress are:

a) *Starvation before handling of fish:* Handling is a source of stress as it puts fish under extreme conditions like overcrowding. Starving the fish for 24 - 48 h (to clean their gut of food and to reduce O_2 consumption) prior to handling will reduce stress and will avoid the deterioration of water quality when fish are overcrowded. Seabass, *Lates calcarifer*, however, require only 1-2 h starvation prior to packing. Because of rigours of journey fish should be carefully checked and injured or weak fish should be removed.

b) *Sedation during handling and transportation*: In situations such as handling or transportation, fish are overcrowded. Therefore, there is a higher risk of skin injuries (scale removal, abrasion *etc.*). To avoid such damages, sedation using approved fish anaesthetics/ sedatives is recommended as it decreases the level of stress and possible skin injuries.

c) *Grading of fish to give a homogeneous population*: When size variation increases in a cage, it often creates competition between the larger and the smaller fish. This can result in stress, especially for the smaller fish. In addition, when feeding, the bigger fish are stronger and get more feed. As a consequence, the smaller fish get weaker and more susceptible to disease. As they get sick, they will also become a source of infection for bigger fish as size variation is also a source of cannibalism (leading to horizontal disease transmission). For seabass, grading is essential during the initial stage of growth due to its cannibalistic behaviour

d) *Good water quality maintenance*: Water quality should be monitored on a regular basis and be maintained at optimal conditions.

e) *Over-feeding to be avoided*: Since over-feeding can induce stress and unconsumed feed will pollute the water, it should be avoided.

f) *Transportation process*: Plastic bags filled with one third with water and the remaining space filled with oxygen prior to sealing and double bagging for safety is better for less than 4cm fry of seabass. Insulated (with thermocol/ saw dust *etc.*) transport box (1t to 3t) mounted on truck can also be used for fish transportation. The tanks should have smooth (round) corners to minimize damage to the fish, and are often provided with aeration facility during transport. Transport problems may be aggravated by high temperatures and by salinity. Therefore, it is better to transport fish during night or packing containers with ice and saw dust (1:1). If fish have to be transported over considerable distances there is also a risk of a build up of toxic metabolites, such as CO_2 and ammonia and increased bacterial load.

g) *Lowering metabolic rate and thus oxygen consumption and waste production*: Through a combination of light sedation and hypothermia lowering of metabolic rate and thus oxygen consumption and waste production can be achieved. Absorption of ammonia and CO_2 and control of bacterial growth through the addition of natural zeolite, a buffer and an antibiotic to the transport media is also practiced (only after standardization).

Good records of water quality conditions, growth and mortalities should be kept so that management procedures can be properly evaluated and modified as and when necessary.

Seed supply and stocking

Any species for which seed is readily available is ideal for cage aquaculture. Those fro which hatchery technology is standardized is ideally suited for cage culture. Wild collected seed can also be used for cage culture if adequate number is available in healthy condition. Nursery rearing is very crucial for all species and specially seabass, with frequent grading and adequate feeding. For seabass, if grading is not done periodically, cannibalism will considerably reduce the stock volume. However, a 30 percent loss in stock is anticipated in normal case during nursery rearing of fry to cage stocking size (20-30 g).

Before stocking the fish to cages, care should be taken to ensure that the temperature of the fish is adjusted to approximately that of their new environment. It is better if transfer is done during evening or early morning hours. When transported using tanks, the volume of water is reduced prior to the fish being transferred by hand or net.

If nets are used, these should be of fine knotless mesh to minimize damage. Feeding of fish on transfer to the cage can commence 3-4 h after transfer.

Feed management

Feed and the feeding regimes need proper management for better health and growth of the cultured stock. However, the quality and safety of feed and the use of fish medicines and chemicals must be controlled by concerned agencies so that it will integrate aquatic product security examination, environmental monitoring and fish disease prophylactic systems at different levels.

Feeds and feeding

Feeding is essential in cage farming especially if stocking rate is towards the higher side or to the maximum carrying capacity. As in other aquaculture operations, the feeding cost accounts for an estimated 40-60% in cage farms also. Formulated feed meeting with the complete nutritional requirement of carnivorous fish is used in many parts of the world for such species. However, the cost is high for such feeds. Fresh or frozen minced and chopped trash fish still forms the main stay feed for a number of carnivore groups cultured. Economic factors and problems with diet formulation, feed storage and distribution are the principle reasons why this type of feed remains popular in some quarters.

The advantages of using trash fish are:

- Cost effective
- Availability (of the 3mt in India @ 40 % is trash and used in chicken and swine feed. Why not fish feed to fish rather than to poultry and livestock?)

The problems in using trash fish are:

- Seasonal Fluctuation in flesh quality
- High moisture content and expensive to transport (best for farming operations sited close to fish landing or processing centres).
- High wastage, which affects water quality
- Increased bacterial load in raw diet which may lead to bacterial infection.

Dry diet are less polluting, stable in water, nutritionally complete, easy to transport and store, available in floating and sinking forms, *etc.* however, they are expensive and formulation not known and cost escalates from one operation to the next depending on demand.

Storage of feeds

Storage facilities are essential for cage fish farming operations. Feed bags should be stored without open access to moisture and thus to prevent fungal attack. Trash fish may arrive at the farm in either frozen or unfrozen state and since fish spoils rapidly it should be checked for freshness before being stored. Smell and appearance should be sufficient indicators of quality. Cold storage is ideal for trash fish.

Shelf life of various feeds

Feed type	Storage and duration
Dry feeds (Rice bran, wheat middling)	With < 10% moisture content and stored in cool , dry and pest free environment; can be stored for several months
Trash fish frozen	feed with high fat content up to three months at – 20°C; low fat content more than one year a t– 20°C
Pellet feeds	2-3 months

Feeding

Feeding should be done throughout the culture period at varying levels depending on the growth rate and natural feed availability. Hand feeding is done in most cases and is recommended for small scale farmers. However, mechanical feeders are used in large scale cage farms – demand feeders and automatic feeders are the two types of feeders used.

Feeding rings can be used if floating pellets are used. Feed trays set inside the cage at different positions can also be used for feed distribution. By hand feeding, the feeding of fish can be watched and can be fed till satisfaction. While doing so, the stocks health status can also be monitored (stressed or sick fish stops feeding first). Frozen trash fish is thawed first, chopped and minced and broadcasted over the surface using a shovel or scoop.

Water quality management

Water quality management is a key ingredient in a successful fish culture practice. Most periods of poor growth, disease and parasite outbreaks, and fish kills can be traced to water quality problems. Water quality management is undoubtedly one of the most difficult problems facing the fish farmer. Water quality problems are even more difficult to predict and to manage

Oxygen

In cage culture situations, if proper water exchange is not there, low dissolved oxygen is particularly acute because the fish are crowded into such small areas. Most fish kills, disease outbreaks, and poor growth in cage situations are directly or indirectly due to low dissolved oxygen. Dissolved oxygen management is one of the most critical management techniques that must be learned by a fish farmer. The cage net mesh should be kept open always to have maximum flow of water and no drifting objects or plants should obstruct water flow in the cage system.

Temperature

Temperature is critical in growth, reproduction and sometimes survival. Each species of fish has an optimum temperature range for growth, as well as upper and lower lethal temperatures. Below the optimum temperature feed consumption and feed conversion decline until a temperature is reached at which growth ceases and feed consumption is limited to a maintenance ration. Below this temperature is a lower lethal temperature at which death occurs. Above the optimum temperature feed consumption increases while feed conversion declines

pH, ammonia and turbidity

The desirable range of early morning pH for fish production is from 6.5 to 9. Both ammonia and nitrite are toxic to fish. The level of ammonia toxicity depends on the species of fish, water temperature, and pH. A healthy phytoplankton bloom (green water) is one with a Secchi disc visibility of 15 to 24 inches and clarity above 24 inches indicates poor phytoplankton productivity. Visibility of less than 12 inches indicates a plankton bloom which is too dense and may cause low dissolved oxygen problems. Visibility of less than 6 inches is critical for fish.

Routine Management

Water quality monitoring

Monitoring of water quality is essential

- To avoid losses caused by lethal changes in water quality
- To evaluate site and configuration of cage
- To maintain optimum stocking and feeding requirements
- To evaluate the general condition of stock, so that if stressed, can avoid handling.
- To gain information of long term changes in water quality at a site so that variation in production may be properly evaluated.

Data on dissolved oxygen and temperature are essentially collected. Measurements to be taken preferably at early morning hours and mid-day, and readings of both inside and outside cages and at cage surface and bottom should be made.

Data on nitrogen (ammonia, nitrite and nitrate) and dissolved phosphorus, pH, turbidity *etc.* will give a clean idea about the cage environment.

Waste control and effluent management

Cage-farm wastes are usually in the form of uneaten feed and fish faeces. Feed is usually the major input to the cage-farm operations. Feeding should be scheduled in such a way to ensure that feed wastage is kept to a minimum. Many operators now use extruded fish feed of improved digestibility to maximize assimilation and minimise loss to the environment. Use of floating feed is vital for cage-farm operations. Mooring cages in deep waters, leaving 3-5 m bottom space and where good current flow results in cage wastes being easily flushed away, thereby avoiding organic build up under the cages.

Health management practices

The objective of health management is to maintain a good health status, assuring optimum productivity and the avoidance of diseases. In aquaculture, the economic risk associated with diseases is high. It represents a potential loss in production through mortality and morbidity, and might decrease investor confidence. Moreover, the cost to treat diseases when they are already well established is high and treatments are often initiated too late and are therefore rarely effective. Thus, aquatic animal health management must be a global strategy that aims to prevent diseases before they occur.

Aspects of health management practices – to improve fish health and survival

Responsible transportation of live aquatic animals: Increased trade of live aquatic animals and the introduction of new species for farming, without proper quarantine and risk analysis in place, result in the further spread of diseases. A scientific process should be undertaken to assist decision making regarding the risks versus the benefits for the species intended to be imported.

Hygiene, disinfection and biosecurity: Hygiene and biosecurity aims at preventing the introduction of any disease agent into the farm and should limit the spread of disease. Good sanitation practices in cage-farming systems are difficult to implement as there are no filters or barrier between the cage environment and its surroundings (where pathogens can be found). However, it is necessary to reduce the risk of contamination by simple management practices aimed at reducing the pathogen pressure in the environment. Such practices include proper system maintenance by removing excess suspended particles and uneaten food which is a potential substrate for pathogens. Moreover, their presence reduces water flow and therefore the available dissolved oxygen for the fish. The frequency of net cleaning depends on the severity of the fouling. The removal of dead or moribund fish on a daily basis is an important sanitary measure, as well as important for record keeping. Dead fish, especially in tropical water, decay quickly and can be a critical source of horizontal disease transmission as the remaining live fish will tend to eat the dead fish.

Selection of hatchery-raised fingerlings: The overall health status of fry and fingerlings is a critical factor for a successful production cycle. When choosing a species to be farmed, preference should be given to species that are already available from hatcheries. The attention given to fish in the hatchery, and the availability of specific larval diets required to obtain strong juveniles, will allow for a constant supply of good quality fingerlings. Presently, the availability of hatchery-raised fingerlings is limited. The availability of hatchery-raised fingerlings should certainly increase in the near future.

Record keeping and disease monitoring: Often, in small scale operations, recording of farming parameters such as daily mortality, feed consumption, growth rate and water quality parameters is not standard. Record keeping is crucial in understanding the epidemiology of diseases and can also allow us to identify critical management points in the production cycle. The collection of this historical data will help us take early action in the case of disease outbreaks.

Proper disease diagnosis – a prerequisite for effective health management

As aquatic animal health management is about implementation of control measures to prevent the incidence of diseases, it is a prerequisite to have a good understanding of diseases that might occur in a particular fish species. Therefore, adequate attention should be given to disease diagnosis and epidemiology studies.

Fish husbandry and management

Choosing the optimal fish density is important in cage culture. Depending on the fish species and water quality conditions (especially the oxygen saturation of the water), there is a certain fish density that should not be exceeded. A common mistake is to increase the stocking density to compensate for a decrease in survival rate. This is a source of stress for the fish that can lead to skin injuries, low performance and a higher susceptibility to disease. In contrast, stocking fish optimally will allow fish to grow to their best potential and decrease the risk of disease outbreaks.

Regular monitoring of fish from disease point of view is also essential. Often the first signs that something is wrong can be surmised from changes in behaviour. Farmers should therefore be used to observing their fish without unduly disturbing them, and form a general picture of how they are disturbed and behave under normal cycle of environmental conditions which occur at the site, *i.e.*, dawn/mid day/dusk, high tide/ low tide, feeding/non-feeding *etc.* changes in feeding behaviour is an indication of poor health.

If something wrong is observed , then some fish should be sampled and examined further, for changes in general physical appearance (deformed spine), skin (colour, presence of lesions, rashes, spots or lumps, excessive mucus), eyes (bulging eyes, cloudy lens), fin and tail (erosion) are all signs that something is wrong.

Fish sampling should be done regularly so that the growth of stock is monitored. This information with records of mortalities is necessary for making a number of management decisions, such as determination of stocking and feeding policies and timing of harvesting. Recording of mortalities is essential, as a change in incidence of mortalities can help warn of the onset of disease outbreak and gives the farmer valuable information in the progress of the stock and management strategies (stocking densities, feeding rates *etc.*)

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

Maintenance of cages and gear

Irrespective of the damage that can be caused by storms, predators, drifting objects, poachers, all materials used in construction of cages have a definitive life span and will eventually wear out. Cages, nets and moorings therefore must be checked at intervals for signs of damage and wear and tear and repaired or replaced if necessary, as not only cages and stock be put at risk, through neglect, but human life may also be endangered. Mooring must be checked regularly by divers, particularly after heavy wind/storms. Mooring level should be kept free from fouling and worn shackles replaced.

Cage nets may be checked during cleaning, which is done more frequently during cage culture. Divers may have to go down and observe the net every week or so, during favourable weather conditions. Small tears may be repaired at the site itself, while major repairs should be done on shore only.

In marine environment fouling is a major issue and in rotating design (single point mooring system) it is reduced. Therefore, the nets have to be frequently changed. In any case, nets of any particular mesh size should be exchanged quite often for ones with larger size as the fish grow. Mesh size should be carefully selected at each stage of growth too. If too small mesh size is selected, then matter exchange is restricted and if too large, escape is possible. The frequency of net charge varies from once in a week to once in a year depending upon the site location, materials used, season and management and design of cage.

Net cleaning can be done physically or by chemical treatment. Physical cleaning involves removing and scrubbing the net and drying. For chemical cleaning bleaching powder or formic acid (3%) can be used. The rate of bio-fouling on cage frame is much slower than on net cages, and doesn't need more frequent cleaning. Cage frames are usually cleaned *in situ* using a hand brush both above and below the water line to dislodge weed and accumulated debris.

Integration of seaweed (*Kappaphycus alvarezii*) and pearl oyster (*Pinctada fucata*) along with Asian seabass (*Lates calcarifer*) in open sea floating cage off Andhra Pradesh coast

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Introduction

Aquaculture is growing very fast and its growth is expected to continue and it is necessary to supply fish for the ever growing population of our country. In India, fish production and consumption is considered to be important and needs to be promoted. As capture fisheries have almost become stagnant, diversification of aquaculture is highly necessary. Considering the limited scope of freshwater aquaculture and the availability of vast coastline, open sea cage culture gained importance in the present day mariculture practice. Open sea floating cage culture is an alternative sustainable practice for rearing fish and shellfish species and polyculture along with seaweeds may also improve profitability and sustainability. Open sea cage culture is an aquaculture production system where high density of fish is cultured in floating cages. Floating cages are widely used in commercial aquaculture and individual cage units of desired shapes and sizes can be tailored to suit the needs.

The release of NO_3 and PO_4 from the high density of fish stock and due to heavy feeding from the nearby areas of the cage and to utilize this form of nitrogen and phosphorus as the source of nutrient for the cultivation of valuable sea weed, the study has been conducted to see the possibility of co-cultivating sea weed *Kappaphycus alvarezii* and Asian seabass *Lates calcarifer* in open sea floating cage in Bay of Bengal off Visakhapatnam coast in Andhra Pradesh. Cage culture is an alternative sustainable practice for rearing fish and shellfish species and polyculture along with seaweeds and pearl producing oysters may also increase production. In this experiment, at the open sea cage demonstration project site at Visakhapatnam co-cultivation of Asian seabass (*Lates calcarifer*), the seaweed (*Kappaphycus alvarezii*) and the marine pearl producing oyster (*Pinctada fucata*) was undertaken in the floating cage. It was carried out in an offshore area near the Visakhapatnam Regional Centre of Central Marine Fisheries Research Institute, off Andhra Pradesh coast, Bay of Bengal, India.

Basics of the integrated system

Integrated cage culture with sea weed, oysters and fish is a method of raising animals and weeds needs a floating cage which permits a good water exchange and waste removal into the surrounding water. Adequate water circulation is essential to make the nutrients available for the growth of the sea weed. However, the following criteria need to be given attention.

Site selection

Appropriate site selection is important for successful enclosure aquaculture. Sheltered, weed-free, shallow bays (6-10 m deep) are the ideal locations for installing cages. The sites should have adequate circulation of water, with wind and wave action within moderate limits. Excessive turbulence may lead to wastage of fish energy for stabilizing themselves, loss of feed and growth of weed also may not be proper. The other major considerations are that the water should be pollution-free, availability of seed in the vicinity, easy accessibility to the site and a ready market for fish and the weed. Flowing waters with a slow current of 1.0 to 9.0 m per minute are considered ideal for cage siting. It is desirable to install cages a little away from the shore to prevent poaching and crab menace but within the limit of reach by the persons who monitor daily the activities.

Species selection

Selection of species for cage culture should be based on factors like the local demands and availability of quality seed, fast growth rate, adaptability to the stresses in enclosures due to crowded conditions, ready acceptance of trash fish feeds and good market demand. Seaweed is opted at places where it can be disposed off as fast as possible.

Cage Materials, mooring and anchoring

The cage should be durable and strong, but light weight and allow complete exchange of water volume every 30 to 60 seconds by using a minimum of 13-mm square mesh size. There should be a free passage of fish wastes and should be inexpensive and readily available. It should have a proper net to hold the crop as well as to protect from the predators. The outer ring should have been supported with cat walk for daily observation of the fish, weed and the oysters. Proper care must be taken with regard to floating system and buoyancy, a good service system for collars and fittings and a good mooring system and a proper anchorage to hold the cage. A mooring system must be powerful enough to resist the worst possible combination of the forces of currents, wind and waves without moving or breaking up.

Cage positioning

Positioning of the cage for good growth of fish and weed should be done in open areas with good water circulation, but protected from strong currents and high waves. It should be away from still or stagnant water where poor water quality may stress or kill fish and improper growth of the weed. It must be placed at least above 1 m above the bottom sediments.

Water quality considerations

A good water area without any pollution is desired for the culture of fish or shellfish and sea weed. Biofouling caused by organisms that attach themselves to the cage and restrict water exchange. Area away from marine biofouling organisms include algae, oysters, clams, and barnacles is suited or else cleaning at regular intervals are required to facilitate a good culture activity.

Security considerations

Cages should be placed where they can be easily monitored if poaching is a serious consideration.

Methods applied

Experimental circular grow-out cage (15 m diameter and 6 m deep) with floating frames was used for the purpose. Fingerlings of 80-95 mm average length which were reared and acclimatized in 5 ton capacity FRP tanks at the mariculture hatchery of the regional centre were transferred to the grow-out cage and reared at a suitable density. In order to test the use of available space in the outer ring of the floating cage, thalli of the seaweed *K. alvarezii* were grown in nets tied with plastic rope to the HDPE outer ring of the cage. Simultaneously, epoxy coated iron boxes (2 x 2 x 0.5 ft) with plastic net covering were used to grow the spat of *P. fucata* were attached to the outer ring of the cage. The spats which were bred and grown in the mariculture hatchery of the centre were used to stock in the boxes with the average initial DVM 45 mm, AVM 38 mm and cup width 13 mm and an average weight of 6.22 gm. Regarding management, fish was fed only with trash fish available at the Visakhapatnam fishing harbour at different rates as per the biomass and no other management was undertaken for the oysters and the seaweed. Sea weed brought from Mandapam area of Ramanathapuram district of Tamilnadu and it was grown in the mariculture hatchery of Regional Centre of Central Marine Fisheries Research Institute, Visakhapatnam, Andhra Pradesh. It was cut it in to fragments of 30 g each and allowed to grow further, in the 1 ton FRP tanks with 30 ppt salinity and about 30% water exchange everyday. Further, it was grown in offshore area of Lawson's Bay at Visakhapatnam stocked in plastic net pouch of 0.5x05 ft. and the growth was recorded and compared with onshore culture conditions. After sufficient amount has been harvested it was re stocked in plastic net pouch of 2.0x2.0 ft. the outer floating frame of the open sea floating cage in square plastic rope nets of (2x2 ft) size in which 150 gms. of sea weed were stocked. Growth of oysters, seaweed and fish yield reached remarkable production rates with the increment in case of fish about 212.5 %, in case of oysters with 28.8 % in DVM, 23.68 % in AVM, 61.53 % in cup width and 296.62 % in weight and in case of seaweed the increment was 456.66 %.

Advantages and disadvantage

Advantages:

- Use of existing coastal water bodies with possibility of making maximum use with greatest economy with lower capital cost investment as compared to land-based farms.
- With its technical simplicity open sea floating cage farms can be established or expanded which further helps to reduce the pressures on land resources.
- Easier stock management and monitoring compared with pond culture and it shows the possibilities of combining several types of culture within one water body.
- Easy for daily observation of the stock allows for better management.

Disadvantages:

- Stock is vulnerable to external environmental hazards like cyclones and currents and the water quality problems like algal blooms and biofouling organisms. Rapid fouling of cage walls requires frequent cleaning of net.
- Back up food store hatchery and processing are necessary to overcome feeding in the fishing ban timings.
- Feed losses possible through cage walls due to water currents and sometimes the small fish enter cages and compete for food.
- Security management is must to avoid poaching as the high density of crop is in confinement.

Conclusion

With the results presented, it can be concluded that in open sea floating cages, the cultivation of fish, sea weed and oysters either pearl producing or edible, provides a reasonable solution to cultivate species that are economically valuable and increase profitability without much investment. In the present study, the conditions of oysters and the seaweed were very healthy and no negative interferences could be observed in co-culturing fish, oyster and seaweed in the same cage indicating the treatments and harvests remaining independent. Further improvement with regard to designing of the system can be done when battery of open sea floating fish cages are tagged to each other with sea weeds and oysters attached to the outer floating frames. It provides scope for further research to incorporate with species that could grow well and also act as an efficient biofilter for this integrated system.

Nutritional requirements of Asian seabass, *Lates calcarifer*

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Introduction

Asian seabass (*Lates calcarifer*) has emerged as an important candidate finfish species for aquaculture in many parts of the world. Availability of seed and appropriate feed are the two important prerequisites for development and propagation of aquaculture of any fish species. After considerable efforts and extensive research, the Central Institute of Brackishwater Aquaculture (CIBA) has succeeded in developing captive brood stock and seed production technology for Asian seabass. Research efforts on nutritional requirements and development of suitable formulated feeds have been in progress simultaneously at CIBA. The nutritional requirements of fish vary with different growth stages and depend upon the feeding habits that change according to the morphology of digesting system. Considerable effort has been made in Australia, Thailand, Philippines and more recently Israel, in defining the nutritional requirements of this species in order to improve production. Understanding the nutritional requirements of the candidate species is the first and essential pre requisite for development of cost effective, efficient and eco friendly feeds.

Nutritional requirements

Investigations on Asian seabass (also known as Bhetki in Bengal, Koduva in Tamil, Kalanchi/ Narimeen in Malayalam) have been mainly concentrated on energy nutrient requirement in the diet. Recently information on micro-nutrient needs such as vitamins has started coming in. The nutrition research undertaken falls clearly into two streams *viz.*, requirements during hatchery and nursery phase and requirement in grow out period.

Requirements during hatchery and nursery phase

The nutritional requirements of larvae that have a body mass less than few milligrams are not very much understood. Based on the composition of the yolk, live prey and larvae themselves it is assumed that the nutritional requirements of larvae were higher than those of the juveniles. The nutritional requirement is not similar for larvae and juveniles. Indeed, a dietary formulation sustaining good growth in juveniles induces poor results in larval growth and survival.

Most of the works conducted on nutritional requirements in fish have focused on lipid requirements. Until a few years ago as there was no compound diets available for larvae, studies on nutritional requirements are limited in general. However, studies on lipid requirements were easier to conduct because total lipid content or fatty acid profile can be modified in live prey, while it is quite impossible to change the amino acid profile of an organism. Nevertheless, growth is essentially protein deposition, and adequate proteins must be supplied to sustain optimal growth.

Lipid requirements

Lipid sources and total lipid

Eggs of marine fish exhibit high lipid content around 20% and reported that fertilized eggs of seabass contain about 27% lipid on DM basis (Syamadayal *et al.*, 2003). Lipids included in microparticulate diets come partly from fish meal or other meals incorporated as protein source and are generally derived from marine sources. Cod liver oil, roe oil, sardine oil or menhaden oil are added as triglycerides in larval diets. In seabass larvae, growth and survival were directly related to the lipid content of the diet. Best results were obtained with the diet containing 30% lipid, as a mixture of cod liver oil and soy bean lecithin (Zambonino Infante and Cahu, 1999).

Phospholipid

Beneficial effects of phospholipid (PL) incorporation in larval diet was reported as early as in 1981 (Kanazawa *et al.*1981) and in 1993, he has reported that fish larvae were incapable of synthesizing PL at a sufficient rate to meet the requirement during a period of high cell multiplication; hence PL is required in larval diets. Studies have been conducted at CIBA to determine optimal level of phospholipids in seabass larvae using soybean lecithin as phospholipid source. Good growth and survival have been obtained by feeding seabass larvae with a diet containing fish oil and lecithin at 5 and 10% respectively. Sargent *et al.* (1999) are of the opinion that the ideal diet for marine fish larvae would include 10% marine fish phospholipid, since egg or yolk sac larvae exhibit 10% phospholipid concentration.

Essential fatty acid

The n-3 highly unsaturated fatty acids (HUFA) have been identified as essential dietary components for marine fish since a long time as marine fish cannot synthesize them. Special attention was paid to eicosapentaenoic (EPA, C20:5n-3) and docosahexaenoic acid (DHA= C22:6n-3), which are found in large amount in fish cell membranes. Experiments conducted using live prey (Watanabe and Kiron, 1994) or a compound diet (Zambonino Infante and Cahu, 1999) have shown that the optimal level of EPA+DHA in diet for marine fish larvae is around 3% of dry matter.

Protein requirements

Protein sources

Person Le Ruyet *et al.* (1989) weaned 23-day-old seabass, *Dicentrarchus labrax*, with a compound diet including squid, shrimp and hen eggs. A mixture of fish meal, shrimp meal, squid meal, lactic yeast was used in a diet given to 25-day-old seabass larvae (Zambonino Infante and Cahu, 1994). Protein sources were selected following their amino acid profile and incorporated in microdiet as the only protein source. Fish meal has been used as the main protein source in diet formulated for seabass (Zambonino Infante *et al.*, 1997) up to a level of 65% in the diet used for feeding 20 day post hatch (dph) larvae. The first attempt to determine optimal dietary protein level for seabass at very young stages was conducted by feeding larvae from Day 15 to Day 35 with isoenergetic compound diets incorporating a gradient in protein level (fish meal plus casein hydrolysate @ 30-60%). The best growth was obtained with 50% protein.

Amino acid requirements

No information is available on the amino acids requirement for marine fish larvae and their optimal level in a diet. However, the profiles of essential amino acids of fish body tissue are generally considered as a good indicator of their amino acid requirements.

Molecular form of the protein fraction

The role of free amino acids and short peptides in diet on larval development has been investigated by several authors. As early as 1989, Fyhn (1989) suggested that free amino acids constitute a substrate for energy production in marine fish larvae during early larval stages and the larvae during young stages need an exogenous supply of free amino acids. Watanabe and Kiron (1994) considered that it is not clear if fish larvae have a sufficient ability to digest food protein or whether free amino acid must be provided by diet. In the same way, the incorporation of 10% essential amino acid mixture in fish meal based diet failed to improve growth and survival in seabass larvae compared with larvae fed diet with the same nitrogenous level brought as whole protein (Cahu and Zambonino Infante, 1995). Nevertheless, the dietary incorporation of free amino acids induced an increase in trypsin secretion in early larvae stages suggesting that pancreatic digestion would be improved. Beside their nutritional function, free amino acids play a very important role in first feeding by acting as chemo-attractant. Protein hydrolysate has been since a long time considered as an advantageous protein form for fish larvae and the product was incorporated in most of the larval diets at least for improving microparticle physical properties. Recent experiments have shown evidence of the high nutritional value of protein hydrolysate and its role in larval nutrition. Zambonino Infante *et al.* (1997) showed that a 20% replacement of fish meal by di and tripeptides (obtained from fish meal hydrolysate) in diet resulted in improvement of the main biological parameters in seabass larval rearing: growth, survival and skeletal formation. Incorporating di- and tri-peptides to the diet led to a growth improvement when an amino acid mixture failed to induce the same effect. Hydrolysates are beneficial to larvae, while they do not affect, or in some cases, depress juvenile growth. These results suggest that fish larvae have specific nutritional requirements which can be understood by the analysis of larval digestion.

Nutritional factors affecting larval morphogenesis

Protein hydrolysate enhances larval morphogenesis. The molecular form of the dietary protein supply, native proteins or hydrolyzed into oligopeptides (around 20amino acids), has probably an indirect effect on morphogenesis. Dietary lipids play an essential role in larval growth and survival. Growth and normal morphogenesis increased as the dietary inclusion of phospholipids and vitamins, particularly vitamin A.

Requirements during grow - out phase

Protein and amino acids constitute the key group of essential nutrients required by Seabass for synthesis of protein and subsequently growth. Several studies have been undertaken to define protein requirements, although limited studies have been undertaken to examine specific requirements for key amino acids.

Protein

Most of the studies undertaken to examine the requirements for protein in barramundi diets suggest a relatively high protein requirement, consistent with the

Table 1. Summary of protein requirement estimates for barramundi

Crude Protein levels examined (% to %)	Optimal Level (%) (MJ/kg)	Gross Energy level at Optima	Initial Fish Size (g)	Temp (C)	Authors
35 - 55	45 - 55	13.4 – 16.4	n/d	n/d	Cuzon, 1988
45 - 55	50	n/d	7.5	n/d	Sakaras *et al.* 1988
45 - 55	45	n/d	n/d	n/d	Sakaras *et al.* 1989
n/d	40-45	n/d	n/d	n/d	Wong and Chou, 1989
35 - 50	50	50	1.3	29	Catacutan and Coloso, 1995
29 - 55	46 - 55	18.4 – 18.7	76	28	Williams and Barlow, 1999
38 - 52	52	17.8 – 21.0	230	28	Williams *et al.* 2003
44 - 65	60	20.9 – 22.8	80	28	Williams *et al.* 2003

carnivorous/ piscivorous nature of the fish. Seabass being highly carnivorous showed a dietary requirement of 45 – 55% protein. Subsequently Catacutan and Coloso (1995) suggested 42.5% in the diet of the fish. Experiments conducted in CIBA with different level protein feeds on the young-ones of seabass showed a protein requirement of 43 % for this fish. The summary of protein requirement as reported in the literature is given in Table-1.The protein quality in the feed influences the requirement.

The diet energy density and the size of fish used, appear to be the key factors influencing the specific amount of protein required for seabass.

Amino acids

Most of the finfish including seabass show the requirement of the same ten amino acids (arginine, histidine, isoleucine, leucine, lysine, methionin, phenylalanine, threonine tryptophan, tyrosine or valine) as essential. However, determination of quantitative essential amino acid requirement would help in assessing the protein requirement more accurately. There have been several estimates of some specific amino acid requirements for barramundi. Coloso *et al.* (1993) estimated the requirement for tryptophan to be about 0.5% of dietary protein. The requirements for methionine, lysine and arginine have also been determined to be about 2.2%, 4.9% and 3.8% of dietary protein respectively (Millamena *et al.* 1994). It has been reported that excessive dietary tyrosine can cause kidney malfunction in barramundi (Boonyaratpalin, 1997).

A series of experiments by Australian researchers examined the capacity of barramundi to utilise crystalline and protein-bound amino acids. One study, based on the addition of crystalline lysine to a wheat gluten based, high-protein diet, compared its utilisation to complementary diets modified to have an equivalent level of lysine enrichment, but with protein-bound amino acids. A second study examined the similar addition of crystalline amino acids into a lower protein diet. Both studies showed that the utilisation of the crystalline amino acids was as effective as that of protein-bound amino acids, but only at the low inclusion levels in the high-protein diet. Estimations of essential amino acid requirements have also been made based on the composition of the body tissues relative ratios of key amino acids to lysine, usually regarded as the first limiting amino acid in most formulated diets.

Lipid

Lipids comprise an important dietary energy source for seabass and are also a source of essential fatty acids. Much work has been devoted to exploring the inclusion of lipids in barramundi diets to increase their energy density. At protein levels of 45% to 50% Sakaras *et al.* (1988; 1989) observed best growth from barramundi fed diets with 15% to 18% lipid content. Studies also showed a similar growth from barramundi fed diets with either 9% or 13% lipids, but noted that feed conversion ratio was significantly lower with the higher lipid levels. Studies by Catacutan and Coloso (1995) examined inclusion levels of 5%, 10% and 15% lipids with three protein levels (35%, 42.5% and 50%). Growth rate was highest at the 15% lipid level, provided protein was also at the highest levels (50%). Similar growth was also observed of fish fed diets with 10% lipids and 42.5% protein. Somatic deposition of fat was observed to increase with dietary fat levels. In a study of some extruded commercial diets, Glencross *et al.* (2003) found that two diets of similar protein levels, but differing substantially in lipid levels (16% vs. 22%) sustained equivalent growth of 555 g fish, but that the higher lipid levels resulted in a significantly lower feed conversion ratio. These authors suggested that this was primarily a response by the fish to the energy density of the diets.

Essential fatty acids

Long-chain polyunsaturated fatty acids have been shown to provide some essential fatty acid (EFA) value to barramundi (Boonyaratpalin, 1997). Boonyaratpalin (1997), suggested that n-3 EFA levels (primarily as a mix of 20:5n-3 and 22:6n-3) of 1.0% to 1.7% of the diet were adequate to support growth. Catacutan and Coloso (1995) examined the total lipid levels and observed signs of EFA deficiency (fin erosion) at 5% dietary lipid levels.

Growth was significantly affected by the replacement of fish oil with either canola or linseed oils, but not with soybean oil. This observation may be due to the altered n-3 to n-6 ratios. Soybean oil is about 60% linoleic acid (18:2n-6) and therefore would have substantially altered the ratios of the diets more so than either canola or linseed oils, both of which have substantially higher levels of n-3 fatty acids than soybean oil. An optimal n-3 to n-6 fatty acid ratio of 1.5-1.8:1 reported for seabass with an increase in demand at higher water temperatures. A "shock-like" or "fainting" response was observed in some barramundi from treatments where there were low levels of n-3 EFA.

Carbohydrates

Asian Seabass have no specific requirement for dietary carbohydrates. It can derive dietary energy from some carbohydrate sources. Research findings infer that carbohydrate as gelatinised bread flour had some capacity to provide dietary energy to barramundi. Fish fed diets that were iso-lipidic and iso-proteic with 20% carbohydrate performed better than those with only 15% carbohydrates.

Vitamins

The quantitative requirements of vitamins and their deficiency signs in the fish are presented in Table. 2

Table 2. Summary of vitamin requirements (mg/kg of diet) for barramundi

Vitamin	Requirement (mg/kg diet)	Deficiency Signs
Thiamine	R	Poor growth, High mortality, Stress susceptible
Riboflavin	R	Erratic swimming, Cataracts
Pyridoxine	5 – 10	Erratic swimming, High mortality, Convulsions
Pantothenic acid	15 – 90	High mortality
Nicotinic acid	n/a	Fin hemorrhaging and erosion, Clubbed gills, High mortality
Biotin	n/a	
Inositol	R	Poor growth, Abnormal bone formation
Choline	n/a	
Folic acid	n/a	
Ascorbic acid (Vitamin C)	25 – 30a (700b)	Gill hemorrhages, Exophthalmia, Scoliosis, Lordosis, Broken back syndrome, Fatty liver, Muscle degeneration, Poor gill development, Bone deformations
Vitamin A	n/a	
Vitamin D	n/a	
Vitamin E	R	Muscular atrophy, Increased disease susceptibility
Vitamin K	n/a	

Summary of nutrient requirements for seabass:

Nutrient	Requirement in diet
Protein	45 – 55%
Lipid	6 - 18%
Fatty acids (n-3 HUFA essential)	1.72%
Carbohydrate	10 – 20%
Protein : Energy ratio	128mg protein/kcal
Vitamin C	700 mg/kg

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Feeds and feeding of seabass in hatchery, nursery and grow out system using formulated feeds

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The requirement of nutrients varies throughout the life cycle of an individual. At early stages, the requirement of nutrients is comparatively high which declines with age. Also the requirements depend upon the feeding habits that change accordingly to the morphology of digestive system. Considerable effort has been made in Australia, Thailand, Philippines and more recently Israel, in defining the nutritional requirements of seabass in order to improve production (Boonyaratpalin and Williams, 2001). Feeds and feeding are the critical factors that determine the economic viability of commercial aquaculture of the species concerned and this topic assumes much more significance in a carnivore species like seabass. Based on the nutritional requirements we know that this fish requires a high protein high energy diet. Further, being a predatory carnivore in nature, weaning them to formulated feed is the critical factor which influences the success of grow out culture of seabass. Understanding the nutritional requirements of the candidate species is the first and essential pre- requisite for the development of cost effective, efficient and eco friendly feeds.

Feeding of larvae in hatchery and nursery

Larvae of finfish and shellfish are generally fed with live food organisms (phytoplankton or zooplankton or both) in the initial phase. Investigations revealed that the developing larvae do not have the full complement of digestive system developed. The larvae of seabass are no exception to this. Studies conducted at CIBA on the metabolic changes and nutrient turn-over in developing seabass larvae revealed that the growing larvae require the essential amino acids leucine and lysine at higher levels in the larval diets (Syama Dayal *et al.*, 2003). Being carnivorous, seabass larvae are fed with zooplankton such as rotifers for the first two weeks post hatch (PH) and then switched over to brine shrimp (*Artemia*) nauplii. The size of the rotifers plays an important role in the successful rearing of the larvae. Super small size rotifers are preferred for feeding seabass larvae. Since, Artemia is an expensive live-food, its replacement by prepared diets has assumed significance in the hatchery and nursery rearing of fish larvae. In this context, formulated micro particulate and microencapsulated diets have been successfully used for feeding the growing fish larvae.

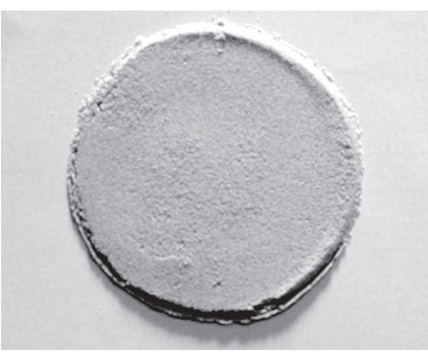
Compounded micro diets for seabass larvae

Physical aspects

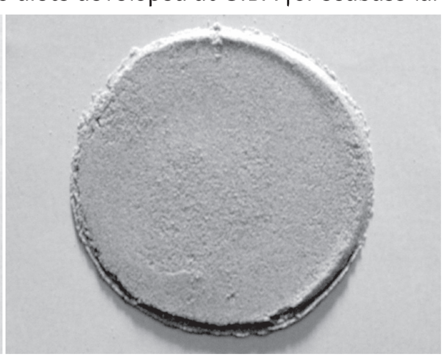
Size

Diet must be prepared as microparticles, whose size must be adapted to the size of the larval mouth. As an example, size of the microparticulated diets used for seabass larval experiments was 50 to 125 ←m at first feeding, then 125-200 ←m from Day 14 to Day 25, then 200-400 ←m to Day 40 (Cahu and Zambonino Infante, 1994). The size of commercial microparticles used in hatchery for seabass or sea bream weaning, used from Day 40, is generally 400 to 600 ←m. Accurate size of the microparticles is essential and must be well calibrated to minimize waste. Particularly, small microparticles (less than 50 ←m diameter) cannot be easily detected by larvae, whereas large ones are difficult to ingest and may even promote a blockage of the digestive valve (Walford *et al.*, 1991). The composition of microparticles must be homogenous; hence, ingredients must be incorporated as very fine meal. The size of the meal particles must be much smaller than the size of the final dietary microparticle. Diet, such as fish meal, must be ground and sieved before being included in microparticles. Concerted efforts made by CIBA scientist lead to the development of micro diets for seabass larvae and the different micro diets used for larval rearing are given below.

Micro diets developed at CIBA for seabass larvae



MD-200



MD-300

MD-400

Manufacturing techniques

Nutrient leaching is one of the problems in developing suitable diets for fish larvae. Particles must be water-stable, palatable and digestible. Diets used for late weaning (after Day 40) in the hatchery can be crumbled, prepared by grinding and sieving pellets, but diets of smaller size must be prepared in microbound, microcoated, or microencapsulated form. In microbound diets, the powdered ingredients are microbound with a water stable matrix such as agar, carrageenan or calcium alginate or by a protein such as casein or zein. Microencapsulated diets are prepared with a cross-linking agent. Microencapsulation produces regular shape and water stable microparticles, but the microcapsules can be difficult to digest. The ability of larvae to break microcapsules depends on the thickness of the capsule coating.

Buyoancy of the diet

Dietary microparticles must be distributed in large excess. Indeed, early stage larvae have a limited movement and microparticles must be caught during their fall in the water column. Good results can be obtained with low density microcapsules (400-600 g/L), sinking at about 25 cm/h average.

Visual and chemical stimuli of the diet

Light intensity, color of microparticles and tank are essential for ingestion. Some pigments, such as asthaxanthin, have been incorporated in microparticles, more for improving the visibility of the particle by larvae than for their nutritional value. Free amino acids, such alanine, glycine and arginine and the compound betaine, have been identified as efficient chemical stimulator for microdiet in gilthead sea bream larvae (Kolkovski *et al.*, 1997).

Thus, larval feed development largely depends on:

- Selection of nutrient specific to the species
- Nutritional balance of formulation

- Retention of nutritional components
- Homogeneity of particles
- Particle size and distribution
- Density of particles
- Water solubility
- Storage stability
- Packing requirements

Apart from providing a balanced diet, the other problem related to larval rearing is the weaning of larvae. Some of the larvae tend to grow faster naturally than the other in the stock, which have to be segregated time to time for higher survival ability and production. These fast growing ones are not necessarily due to nutritionally imbalanced feed but could be due to number of other factors that the hatchery operator usually faces.

Practical feeding of micro diets in sea bass larval rearing

Weaning

The age at which weaning is carried out varies considerably depending on the larval size and rearing method employed. The use of micro diets in larvae is essentially preceded by weaning them to formulated diets. The weaning of larvae can be carried out in following ways:

1. By having a intermediate feeding phase using frozen or freeze dried zooplankton
2. Using simultaneous distribution of live prey and dried feed. It can be started at an early stage.
3. Co-feeding but shortening the live prey co feeding to one or two days. This results in better size homogeneity
4. Starving the larvae and then introducing the micro diets. This method can only be practiced in larvae which are in good health

Micro diets distribution

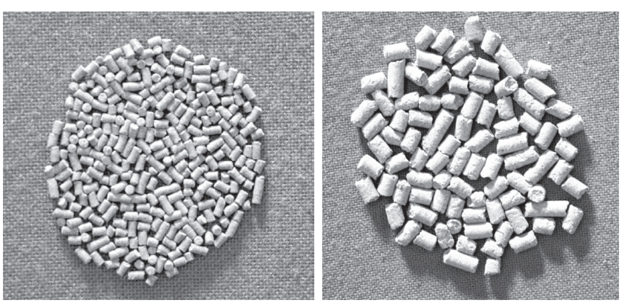
The major bottleneck associated with micro diets feeding are over feeding of larvae and pollution of the environment. The food particles must be made available in large number around the larvae. Small particles float initially and then fall to the bottom. The larvae are not interested in diet that are floating or lying at the bottom of the tank but fed on those particles that pass by their vicinity. Feeding frequencies and feeding period has to be extended as the larvae are very sensitive to starvation. However, they can not ingest their daily ration in two to three meals as the resting time in the digestive tract of larvae are very short compared to juveniles. These features of larvae necessitate continuous and excess feeding. Thus, it is essential to use feeders in larval rearing of seabass using micro diets.

Feeds and feeding of seabass in grow-out culture

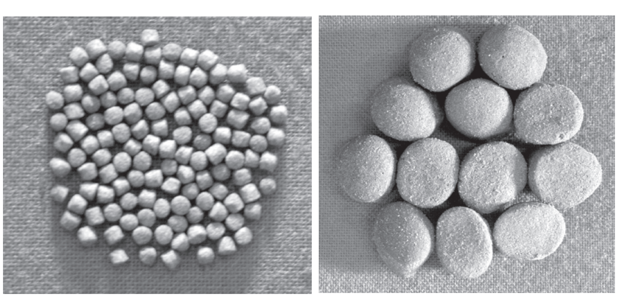
In some of the East Asian countries and also in India, seabass is cultured in grow-out ponds using low value fish (trash fish) and tilapias in fresh condition. Since, procurement and storage of these feed-fish is not only laborious but also quite expensive. Hence, formulated feeds are essential for the propagation of large-scale farming of seabass.

Asian seabass is cultured in Australia and Thailand using formulated feeds (Boonyaratpalin, 1991). As in the case of other carnivorous species, feed formulations for seabass utilize marine fish resources (for meeting protein requirement) and fish oils along with plant protein sources. The animal ingredients are kept above 60% of the formulation to get protein levels in the range of 45-52%. Experiments conducted at Muttukadu field laboratory of CIBA had shown that feeds with substantial fishmeal component (30-40%) only have good acceptability for seabass. Higher the proportions of fishmeal better the acceptability. The texture and size of the feed affects acceptability of the feed. If the flavour and texture of the feed are not to the liking of the fish, it spits out the feed soon after ingesting. The use of animal protein sources such as fishmeal is inevitable in order to keep higher protein levels in the feed. However, plant ingredients such soybean meal and other oil seed residues may be utilized in the feed formulations. Marine fish oils should be included in the feed formulations as a source of polyunsaturated fatty acids (PUFA). Studies conducted at CIBA revealed that the amino acid, glutamic acid, is a useful feed attractant for seabass.

Seabass feeds on moving prey; hence the physical design of the feed plays a very important role. The fish readily accepts soft semi-moist feeds with appropriate size to swallow vis-à-vis the size of the fish. The lower lip of the fish is curved slightly upward, which pose disadvantage while biting the feed. Floating and slow sinking pellet feeds are more suited for feeding seabass. Such feeds are generally processed in extruders.



Sinking feeds for seabass



Floating feeds for seabass

Extruder technology

The basic components in an extruder are a barrel fitted with a die plate and a screw shaft conveyer, which is connected to a high-speed motor. The feed mixture is fed into an extruder by proper arrangement of water/ steam injection facility. The extruder operates at high pressure (14 98 kg/cm^2) and steam (Pressure 5 7 kg/cm^2) injection. Depending upon the characteristics of the feed mixture and moisture content, the pressure develops before the material passes through the die. Because of this the temperature rises and the material is forced through the die and the pressure suddenly drops. The temperature of the material rises to 110 130°C for a short spell of time and cooks the food, gelatinizing the starch present in the feed mixture. This imparts good binding and water stability to the resultant pellets. However, the pellets expand as they come out of the die due to sudden drop of pressure and air gaps develop inside the pellet, which makes them float or sink very slowly. This is an excellent process for producing floating pellets for finfish culture. By adjusting the pressure in the barrel and moisture in the feed, it is possible to prepare sinking pellets by extruder. The new generation extruders are made with twin screw barrel arrangement, which are more versatile for feed manufacture. The size of the pellet diameter ranges from 0.5 mm to 8.0 mm.

The characteristics of extruder pellets are

- Reduction in pellet disintegration and loss in water.
- Increases starch digestibility due to good cooking
- Can be worked with higher moisture and oil (fish oil) levels in the feed.
- Extruder pellets float or sink slowly.
- Making charges for extruder pellets are higher due to high cost of extruders

At CIBA, formulated feeds developed as floating and sinking pellets were successfully tested in grow-out ponds and the fish growth was found to be 500 g in six months.

The fish should be fed at the rate of 10% of their body weight to start with. After four to six weeks the feeding rate may be reduced to 8%. As the fish grow in size the feeding rate should be gradually reduced to 5%, 3% and finally 2%. The total biomass in the pond should be periodically estimated by suitable means (by caste netting) for adjusting the feed. The entire quantity of feed in a day should not be given at one time but divided and fed 3-4 times a day.

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Success in hatchery development of seabass and its potential for commercial cage culture in India

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Introduction

Brackishwater fish farming is considered as one of the potential areas not only as a source for fish production but also ensures the food security, livelihood for coastal community, business opportunity for entrepreneurs and also can earn foreign exchange. Coastal aquaculture has grown tremendously in early 1990s with farming of single species, the tiger shrimp *Penaeus monodon.* However, the shrimp farming faced severe set back due to outbreak of viral diseases coupled with social and other environmental issues. To overcome these issues, it is important to introduce some of the remedial measures in order to revive the aquaculture industry to achieve the sustainable production and one such measure clearly visible is the diversification of brackishwater aquaculture with fish species. It is evident that crop rotation can also decrease the risk of disease outbreak in the pond system. In the recent years, reduction in large scale practices of shrimp farming can be seen in most of the countries, which is not only due to viral disease outbreak but also due to other reasons such as non availability quality and disease free shrimp seed, low in market price, increasing production cost *etc.*, Due to these factors, most of the established shrimp farms have been kept idle without any farming practice. Besides, a rich resource of inland coastal water bodies, which is suitable for fish farming under cages or pens can be also explored to increase the fish production in all maritime states of India.

Culture potential

Among the brackishwater finfish species, the Asian seabass, *Lates calcarifer* is considered as one of the most important candidate species suitable for farming in ponds and cages in fresh, brackish and marine water ecosystem. Asian Seabass popularly known as Bhetki in India is an important brackishwater finfish of the family Centropomidae. The demand for seabass both in domestic market and international market is increasing every year because of its white tender meat.

Development of hatchery technology

Successful seed production in the hatchery depends upon the availability of healthy matured fishes. For selecting potential breeders, viable broodstock under captive conditions has to be developed. Since seabass attains maturity after 2 years of age, one has to wait more than 2 years. To save time, adult fishes could be procured from the commercial catches, transported carefully to the hatchery holding facilities and maintained. Healthy broodstock fishes after observing as protocols can be transferred to broodstock holding facilities like RCC tanks (preferably large tanks of 50 – 100 tonne capacity) or cages or ponds for further maintenance and development providing required feed, quality water and healthy diet for maturation and spawning.

Water Quality Management

Broodstock fishes maintained in captive condition should be provided with environmental quality prevailing in the sea for maturation and spawning. The desirable range of some of the water quality parameters in a broodstock tank are

Temperature	-	28 – 32^{o}C
Salinity	-	28 – 33 ppt
pH	-	7.0 to 8.2
Dissolved oxygen	-	more than 5 ppm
Ammonia	-	less than 0.1 ppm
Nitrite-N	-	less than 0.01 ppm

Feeding and health management

Brood fishes can be fed with trash fishes such as Tilapia or Sardines at the rate 5% body weight daily. The unfed feed can be removed carefully to avoid the contamination. Fishes have to be examined monthly basis to check the parasitic infection if any. External parasites such as *Caligus spp.* and monogenic trematode, *Diplectenum latesi,* can be effectively treated either with 100 ppm formalin for one hr or 1 ppm dichlorvos for one hour.

Maturation

Seabass is a protandrous hermaphrodite fish. They are males during early stage of its life cycle and become females in later period. Reproductive system is very much complicated in hermaphrodite fishes since they go through different phases of hormone secretion which is responsible for gonadal development. Maturation process can be induced/ accelerated either by simulating the environmental conditions prevailing in sea or through the administration of the hormones responsible for maturation and spawning. Seabass spends most of its growing phase in confined waters in the coastal and inland areas and migrates to sea for maturation and spawning.

Induced spawning and selection of spawners

Spawning is a "process of release of sexual gametes". Since sexes are separate in the fish, both male and female matured fishes have to be selected for spawning. The fertilization is external.

Matured female fishes will have ova with diameter more than 450 ←. Males will ooze milt if the abdomen is gently pressed. The gonadal condition is assessed by ovarian biopsy. Brood fishes selected for induction of spawning should be active, free from disease, wounds or injuries. Female fishes will be around 4 – 7 kg and males will be 2.0 – 3.0 kg. Since seabass spawning is found to have lunar periodicity, days of new moon or full moon or one or two days prior or after these days are preferred for inducing the spawning.

Induced spawning by hormone injection

The commonly used hormones in the finfish hatcheries for induced spawning are:

LHRH-a	-	Luteinizing Hormone Releasing Hormone analogue (Available with SIGMA CHEMICALS – USA – ARGENT CHEMICALS)
HCG	-	Human Chorionic Gonadotropins. (Available in Pharmacy – medical shops)
Ovaprim	-	A Glaxo Product

But in the case of seabass LHRH-a hormone is found to be effective with assured result though other hormones can also be used singly or in combination.

Hormone dose

After selecting the gravid fishes the requirement of hormone to be injected is assessed. The dosage level has been standardized as LHRHa at the rate 60 – 70 ←g/kg body weight for females and 30 – 35 ←g/kg body weight for males. The hormone in the vial (normally 1 mg) is dissolved in distilled water of known volume (5 ml). Care should be taken that hormone is thoroughly dissolved. The weight of the brood fishes is assessed and the required hormone is taken from the vials using a syringe. The fish is held firmly. After removing one or two scale just below the dorsal fin – above the pectoral region the syringe needle is inserted into the muscular region and the hormone is administered intramuscularly gently. Since the spawning normally occurs in the late evening hours, when the temperature is cool, hormone is injected normally in the early hours of the day between 0700 – 0800 hours.

Spawning tanks

Spawning tanks size depends upon the size of the fish selected. Normally 10 – 20 tonne capacity tanks with provision for water inlet, drainage, overflow provision and aeration is used.

Sex ratio

Female seabass are generally larger (more than 4 kg.) and the males are smaller (in the size of 2.0 – 3.0 kg). To ensure proper fertilization normally two males are introduced for one female in the spawning tank.

Spawning

Fishes injected with LHRH-a hormone response for spawning after 30 – 36 hours of injection. Prior to spawning gradual swelling of the abdomen will be seen indicating the ovulation process. Spawning normally occurs late in the evening hours 1900 – 2000 hours. At the time of spawning the fishes will be moving very fast and in the water surface a milky white substance will be seen. Prior to spawning activity the males and the female will be moving together exhibiting courtship.

Spawning activity in seabass coincides with lunar periodicity. During full moon or new moon days, the activity is found to be in peak. Hence, induced spawning is done during new moon/full moon Seabass has high fecundity. It is a protracted intermittent spawner (releasing eggs batch by batch). In one spawning the fish may release 1.0 – 3.0 million eggs. The process of spawning will follow during subsequent day also. If the condition is good, both female and male respond simultaneously resulting spontaneous natural spawning and fertilization is effected.

Fertilization

Fertilization is external. In natural spawning of seabass in good maturity condition, fertilization will be 70 – 90%. The size of the fertilized eggs will be around 0.75 – 0.80 mm. The fertilized eggs will be floating on the surface and will be transparent. The unfertilized eggs will be opaque and slowly sink to bottom. Due to water hardening sometime, even the unfertilized eggs, for short duration will be on the sub-surface but will sink subsequently. The fertilized eggs can be collected by any one of the following methods.

Overflow method

After spawning and fertilization, the water level in the spawning tanks can be increased and allowed to overflow through overflow outlet. The eggs will be pushed by the water flow. Below the overflow pipe a trough covered with bolting cloth of mesh size 150 – 200 ←m is kept. The water with the egg is allowed to pass through. The eggs are collected in the next bolting cloth washed and transferred to the incubation tanks.

Scooping/ seine net collection method

Since fertilized eggs will be floating on the surface, a bolting net cloth of 150 – 200 ←m mesh size can be used for collecting the eggs from the surface. The cloth is stretched as net and towed along the water surface. The collected eggs after washing are transferred to the incubation tanks.

Siphoning method

The water in the spawning tank is siphoned into small tank covering with collection net cloth through which the water will be allowed to pass through. The eggs collected in the net cloth are transferred periodically to incubation tanks.

Incubation and hatching

The eggs collected from the spawning tank are washed to remove the debris that would have adhered to and transferred to the hatching tanks for incubation and hatching. The hatching incubation tanks can be 200 – 250 L capacity cylindro-conical tanks. Eggs are kept at density of 100 - 200 nos/litre. Continuous aeration is provided. Temperature of 27 – 28°C is desirable. The eggs will hatch out in 17 – 18 hours after fertilization undergoing developmental stages are given in the following Table:

Embryonic development Stages	Duration
One Cell stage	30 minutes
Two Cell stage	40 minutes
Four Cell stage	45 minutes
Eight Cell stage	60 minutes
Thirty two Cell stage	2 hrs
Sixty four Cell stage	2 hrs 30 minutes
128 Cell stage	3 hrs
Blastula stage	5 hrs 30 minutes
Gastrula stage	6 hrs 30 minutes
Neurula stage	8 hrs
Early embryo	11 hrs
Heart functional and tail movement	15 hrs
Hatching	17 – 18 hrs

The larvae are scooped gently using scoop net and transferred into buckets of known volume. After taking random sample counting depending upon the number required to be kept in the rearing tanks, larvae will be transferred to rearing tanks.

Larval Stocking Density

Freshly hatched healthy larvae (Hatchlings) from the incubation tanks are transferred carefully to the rearing tanks. Larvae are stocked initially at the rate 40 – 50 nos/litre. Depending upon the age and size, the larval density is reduced to 20 – 25 nos/l on 10th day and later and after 15 days, the density is maintained around 10 – 15 nos/l.

Feeding the Larvae & Live Feed production

The following live feeds are very important for feeding the larvae

Algae Green unicellular algae like *Chlorella* sp., *Tetraselmis* sp., *Nannochlorpsis* or *Isochrysis* sp. are needed for feeding the live feed zooplankton.

Rotifer Rotifer (*Brachionus plicatilis*) or *B. rotundiformis* is the most preferred diet for the fish larvae in their early stages.

Artemia Brine shrimp, *Artemia* in nauplii stage are required for feeding the larvae from 9th day. *Artemia* with its natural nutrient profile required for larval development of fish is used in all the hatcheries. .

Whatever good the culture system may be in many cases, Rotifer or *Artemia* nauplii produced in the hatchery may not be having all the nutrients required for the larvae, (especially the unsaturated fatty acids), the cultured Rotifer/*Artemia* are enriched with nutrient rich media and then fed to the larvae.

Water Change

Water quality in the rearing tanks is very important for better survival and growth of the larvae. Water provided to the larval rearing tanks should be free from flagellates, ciliates and other unwanted pathogenic organisms. Water should be filtered through biological filters, pressure sand filters. UV radiation treatment is also given, to get rid of the pathogenic organisms. If chlorine treated water is drawn, residual chlorine should be removed, since, fish larvae are highly sensitive to chlorine and water should be used only after de chlorination.

In the larval rearing tanks, the larvae stocked as well the live feed supplied for the larvae will excrete nitrogenous metabolites and other debris also will accumulate. They have to be removed carefully. The debris and bottom sediment are removed by siphoning using siphon tubes. The bottom debris is slowly siphoned out along with water into a trough with filter net. To maintain water quality in the larval rearing tanks, 30 – 40% water change is done daily. The salinity should be maintained around 30 ppt. And the desirable range of temperature is 27 – 29°C. The water level reduced (30 – 40%) in the rearing tank is leveled up with filtered quality seawater and green water after taking cell count of the algae in the rearing tank.

Algal water is added daily up to 15th day. After bottom cleaning and water reduction, while water change is done, algal water is also added depending upon the concentration, (around 20 thousand cells/ ml in the rearing tank Algal water added should not be contaminated since in the open culture there is chance of contamination by flagellates, ciliates and filamentous algae which will be toxic to the fish larvae. Apart from being a source of feed for the rotifers in the tank, the algae also help in the conversion of harmful excretory products like ammonia and other metabolites in the rearing container into less harmful nutrients.

Feeding

Rotifer (*Brachionus plicatilis*) is given as feed to the larvae from 3rd day. Rotifer is maintained in the larval rearing tanks at concentration at the rate 5 nos./ml initially. From 4th day to 15th day the rotifer concentration is increased to 10 – 20 nos./ml gradually. Every day after water exchange, the food concentration in the tank should be assessed and fresh rotifers should be added to the required concentration. In the early stages (3 – 5 days) the larvae may not be in a position to ingest the large sized rotifers. Hence after collecting the rotifers from the tanks small sized rotifer less than 1500 ←m should be sieved using suitable mesh size bolting cloth nets. . From 6th day assorted size rotifer can be given as feed. *Artemia nauplii* are given as feed along with rotifers and green water from 9th day. By this time the larvae will be around 4 mm TL in size. Larvae can be feed exclusively with *Artemia* from 16th day to 24th day. The density of the brine shrimp nauplii in the rearing medium is maintained at the rate 2000 nos./l initially and gradually increased to 6000/l as the rearing days progress. The daily ration of *Artemia* nauplii feeding is adjusted after assessing the unfed *Artemia* in the rearing tank at the time of water exchange and the larval density.

Feed density/quantity to be given to seabass

By 21st day the larvae will be around 10 – 11 mm TL in size after completing larval development stages. From 25th day the larvae can be fed with *Artemia* sub adult (biomass) along with cooked minced fish/shrimp meat. The fry can also he weaned slowly to artificial feed.

Under circumstances, when the rotifers could not be fed with marine *Chlorella* adequately, the nutritional quality of such rotifers may be poor. In such case, the rotifers can be enriched with special enrichment media. Enrichment is done by keeping the rotifers in emulsified enrichment medium like SELCO DHA or cod-liver oil for 18 - 24 hours. By this process, the animals will ingest the enrichment media which is rich in Poly unsaturated Fatty Acids (PUFA), required for larval growth. The animals are washed and fed to the larvae. In this way Rotifers *Artemia* nauplii/ *Artemia* biomass can also be enriched and fed. *Moina*, a cladoceran can also be fed to the seabass larvae after 21 days.

Grading

Seabass while growing exhibits differential growth rate, hierarchy, resulting different size groups in the same rearing tank. The large one's shooters dominate others for food and space and also prey on them. Seabass larvae are highly cannibalistic and it is more pronounced in early stages. In the rearing tanks, when the larval concentration is more and congregation takes place for food and feeding, the larger ones are tempted to feed on the smaller ones. To avoid this problem, regular grading has to be done. The large sized larvae, ("Shooters") have to be removed. Uniform sized larvae should be kept in the rearing tanks for better survival and growth. Grading should be done once in three days from 15th day or whenever different size larvae are seen in the tanks. Grading can be done using a series of fish graders with different pore size of 2 mm, 4 mm, 6 mm, 8 mm, 10 mm. When the larvae are allowed to pass through the graders, different size will be retained according to pore size of the sieves. Grading may cause injuries leading to mortality. Hence proper care should be taken in handling the larvae. Prophylactic treatment with 5 ppm Acriflavin can be given. By adopting these practices survival rate up to 48% has been achieved with average survival rate of around 15 % in 25 days in larval rearing phase. After rearing the larvae in the hatchery for 25 – 30 days the fry can be transferred to nurseries for further growing.

Nursery rearing

Nursery Rearing in Hatcheries

Seabass fry of 25 – 30 days old in the size of 1.0 – 1.5 cm can be stocked in the nursery tanks of 5 – 10 tonn capacity circular or rectangular (RCC or FRP) tanks. Outdoor tanks are preferable. The tanks should have water inlet and outlet provision. Flow through provision is desirable. *In situ* biological filter outside the rearing tanks would help in the maintenance of water quality. The water level in the rearing tanks should be 70 – 80 cms. Good aeration facility should be provided in the nursery tanks. After filling with water 30 – 40 cm and fertilized with ammonium sulphate, urea and superphosphate at the rate 50, 5 and 5 gm (10: 1 : 1 ratio) per 10 tonne of water respectively. The natural algal growth would appear within 2-4 days. In these tanks freshly hatched *Artemia* nauplli at the rate 500 – 1000 l are stocked after leveling the water to 70 – 80 cm. The nauplii stocked are allowed to grow into biomass feeding with rice bran. When sufficient *Artemia* biomass is seen, seabass fry are stocked at the rate 800 – 1000 nos/m^3. The pre-adult *Artemia* would form good food for seabass fry. The fry would not suffer for want of food in the transitional nursery phase in the tank since the larvae are habituated to feed on *Artemia* in the larval rearing phase. Along with '*Artemia* biomass' available as feed inside the tank supplementary feed mainly minced fish/shrimp meat is passes through a mesh net to make each particle of size of around 3 – 5 mm and cladocerans like *Moina* sp can also be given. The fish/ shrimp meat feeding has to be done daily 3 – 4 times. Feeding rate is 100% of the body weight in the first week of rearing. This is gradually reduced to 80%, 60%, 40% and 20% during 2nd, 3rd, 4th and 5th week respectively. Regular water change to an extent of 70% is to be done daily. The left over feed and the metabolites have to be removed daily and aeration should be provided. In a rearing period of 4-5 weeks in the nursery rearing, the seed will be in the size of 1.5 to 3.0 g/ 4-6 cm with survival rate of 60-70%. Adopting this technique at a stocking density at the rate 1000 nos/m^3 in the hatchery, survival rate up to 80% has been achieved. For the better survival during early growth phase, regular Grading should be done. Vessels/trough placed with different mesh sized nets can be used for grading. When the seed are left into the containers the seeds will be sieved in different grades according to the mesh size and seed size. Care should be taken that the fry are not injured while handling. If the number is less it could be manually done.

Status of seabass farming

Amongst the cultivable fishes in India, Seabass fetches higher price in domestic market varying between Rs.100-250 per kg depending upon the size, the availability and season. It is extensively cultured, in South East Asian Countries like Thailand, Malaysia, Singapore and Australia. Culture of seabass is relatively easy and dependable with fewer risks. Based on case studies, in Thailand it has been estimated that the production of seabass culture was 20.5

kg/m^3. The price of seabass is US$2.27 per kg. The total income from the cage is US $ 46.49 per m^2. The rearing cost is US $ 24.15. The net return is US $ 22.34 per m^3. In the culture operation the fixed cost in cage culture is only 5.9%. The variable costs such as feed, seed, labour etc cost 94.1%. The feed alone costs 63%, followed by the seed cost. Seabass, the value added finfish can be considered as a complementary to shrimp for the sustainability of brackishwater aquaculture.

Traditional Culture

Seabass is cultured in the ponds traditionally as an extensive type culture throughout the areas in the Indo-pacific region where seabass is distributed. In low lying excavated ponds, whenever the seabass juveniles are available in the wild seed collection centers (For eg. April June in West Bengal, May-August in Andhra Pradesh, Sept-Nov. in Tamil Nadu, May to July in Kerala and June-July in Maharashtra. Juveniles of assorted size seabass are collected and introduced into the traditional ponds which will be already with some species of fish, shrimps and prawns. These ponds will have the water source from adjoining brackishwater or freshwater canals, or from monsoon flood. The juvenile seabass introduced in the pond will prey upon the available fish or shrimp juveniles as much as available and grow. Since, seabass by nature is a species with differential growth are introduced into the pond at times of food scarce, the larger may resort to feed upon the smaller ones reducing the number. Seabass are allowed to grow for 6-7 months of culture period till such time water level is available in these ponds and then harvested. At the time of harvesting there will be large fish of 4 to 5 kgs as well as very small fishes. In this manner production up to 2 ton/ha/7-8 months have been obtained depending upon the number and size of the fishes entered/introduced into the pond and the feed available in the pond.

However, this practice is highly unorganized and without any guarantee on production or return for the Aquaculturists. With the advances in the technology in the production of seed under captivity assuring the supply of uniform sized seed for stocking and quality feed for feeding, the seabass culture is done in South East Asian Countries and Australia in more organized manner. The major problem in the development of seabass aquaculture in India is the availability of seed in adequate quantity and the time of need and quality feed for nursery rearing and grow out culture. The former has been overcome and the technology package for the seed production of seabass under controlled conditions is available. The suitable feed for the culture of seabass is being developed. The seed production technology developed by CIBA has already been commercialized and the feed technology will be ready shortly for commercialisation. These technological improvements in the seabass culture have motivated the farmers to select seabass as a candidate species for aquaculture. Farmers have been adopting improved farming practices in seabass culture.

Improved Seabass Culture Methods

The traditional culture method is improved with stocking of uniform sized seed at specific density and fed with low cost trash fishes/formulated feed of required quantity. Water quality is maintained with exchange periodically. Fishes are allowed to grow to marketable size, harvested and marketed for high unit price. Seabass culture can be done in more organized manner as a small-scale/large scale aquaculture in brackishwater and freshwater ponds in cages.

Polyculture

This is an improvement over the traditional method, where the feed, the live fishes, shrimps are deliberately allowed in to the seabass culture ponds to serve as facilitating feed for the seabass in the pond. In the traditional method there is no control over the quantity and quality of the feed entering the ponds which may or may not be adequate. At times of scarcity for feed, the seabass may resort to cannibalism resulting in low survival and production though few fishes will be large size. Under polyculture method, the feed in the form of forage fishes are produced in the culture ponds itself and made available to the seabass fish to prey upon as and when it requires.

Grow out culture of seabass in cages

Fish culture in cages has been identified as one of the eco-friendly at the same time intensive culture practice for increasing in fish production. Cages can be installed in open sea or in coastal area. The former is yet to be developed in many countries where seabass is cultured but coastal cage culture is an established household activity in the South East Asian countries. There are abundant potential as in India also for cage culture in the lagoons, protected coastal areas, estuaries and Creeks. Since, cage culture of seabass has been proved to be a technically feasible and viable proposition this can be taken up in a large scale in suitable areas.

Cage culture system allows high stocking density, assures high survival rate. It is natural and eco-friendly and can be adapted to any scale. Feeding can be controlled and cages can be easily managed. Harvesting is not expensive. Water depth and water current alone the criteria. Even in areas, where the topography of the bottom is unsuitable for pond construction, cage can be installed. Diseases can be easily monitored. Fishes in the cages can be harvested as per the requirement of the consumers, which will fetch high unit price. Above all, cage culture has got low capital input and operating costs are minimal. Cages can be relocated whenever necessary to avoid any unfavorable condition.

Design of Cages

Grow out cages of 20 or 50 m^2 are preferable for easy management and maintenance. Cages are fabricated with polyethylene netting with mesh size ranging from 2 to 8 cm depending upon juvenile fish propose to stocked in the cages. There are two types of cages:

Floating cages: The net cages are attached to wooden frames kept afloat using plastic drums. Anchors or Concrete weight blocks as anchors can be attached to the corners of the net cage at the bottom. These types of cages can be installed in areas with water depth more than 4 meters with feeble water current.

Stationary cages: These are fixed enclosures, which can be installed, in shallow water areas in lagoons, brackishwater lakes having water depth of 2-4 meters. The cage net is fastened to wooden poles erected in the water system at the four corners.

Stocking Density

In the cages, fishes can be stocked at the rate 25-30nos/m^3 initially when they are in the size of 10-15 gm. As they grow, after 2-3 months culture, when they are around 100-150 g stocking density has to be reduced to 10-12 nos/m^3 for space. Cage culture is normally done in two phase – till they attain 100-150 gms size in 2-3 months and afterwards till they attain 600-800 in 5 months.

Feeding in Cage

Fishes in the cage can be fed with either extruded pellets or with low cost fishes as per the availability and cost. Floating pellets have advantages of procurement, storage and feeding. Since, a lot of low cost fishes are landed in the commercial landings in the coastal areas which are fetching around Rs.3-5/kg only used as feed for seabass culture. Low cost fishes like Tilapia available in the freshwater and brackishwater also serve as feed for seabass in ponds and in many cage culture operations. The rate of feeding can be maintained around 20% initially and reduced 10% and 5% gradually in the case of trash fish feeding and in the pellet feeding, the feeding rate can be around 5% initially and gradually reduced to 2-3% at later stage.

In the feeding of low cost fish FCR works out around 6 or 7 (*i.e.* 7 kg of cheaper fishes has to be given for one kg of seabass). In the case pelleted feeding FCR is claimed to be around 1 to 1.2 in Australia. However, the cost effectiveness of the pellet feeding for seabass in grow out culture has to be tested.

Cage Management

Since cages are inside the water and exposed to water current, the debris materials drifted may adhere to the cages and clog the mesh restricting the water exchange. The fouling organism will also attach and clog the meshes. Other animals like Crab may damage the nets. The cages should be regularly checked for clogs and leaks. Damaged nets should be repaired or replaced. The clogging will reduce water exchange, and lead to accumulation of waste products depleting the oxygen causing stress to the fishes, affecting feeding and growth. If the damage is not repaired immediately, the fishes will escape from the cages.

Production

Under cage culture, since seabass can be intensively stocked and properly managed, the production will be high. Frequently culling and maintenance of uniform sized fishes in to the cages will ensure uniform growth and high production. Production of 6-8 kg/m^2 is possible in the cages, under normal maintenance and production as high as 20-25 kg/m^2 is obtained in intensive cage management in the culture of seabass.

Integration of cage culture of seabass with shrimp culture

If seabass can be weaned to feed on floating pellets, because of their addictive nature to selective feed, they will not resort to prey upon shrimp as normally experienced in shrimp culture ponds. If the water depth can be maintained around 1.5-2.0 m, in a pond, cages can be installed in the shrimp culture pond itself and seabass seed weaned to feed on floating pellets can be stocked in the cages and reared. In this way, seabass culture will be a complimentary to shrimp culture.

Conclusion

Cage farming in India can be taken up in pilot scale by utilizing different ecosystem. Cost effectiveness of seabass cage farming with formulated feed in high density in the marine water ecosystem has to be evaluated. The production of value added species like seabass will be increased by using marine and freshwater reservoir cage system. There is need of creation of infrastructure facilities to carry out the nursery rearing and cage farming of the seabass. The safety and security of the stock has to be assured since the fisheries in marine water are prone to poaching. The value and importance of the cage farming has to be taken as massive awareness programme in the surrounding areas. The programme can be initiated as a community programme through fishermen/women co-operatives.

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Importance of water quality in marine life cage culture

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Water quality in marine life cage culture is one of the most important factors that determine production and mortality. Choice of site for marine cage culture is of paramount importance since; it not only affects water quality but also greatly influences the economic viability. Once the site is selected for marine cage culture, there is little that can be done to improve the site, if water exchange is poor.

Criteria for selecting a site for marine cage culture

Environmental Criteria

Depth

Shallow bays with limited depth of water under cages are not favorable for water renewal and generally the settling of wastes. A depth of 10 – 30m at low tide may be considered as ideal condition. Cages should be sited in sufficient depth to maximize the exchange of water, yet keep the cage bottom well above the substrate in order to avoid interaction between the cage bottom and sea floor. Water is drawn into the cage not only through the sides but also through the bottom panel and as the cage bottom approaches the substrate, flows become increasingly impeded. It can cause chemical and bacterial interactions, net damage and predation of the fish by crab and bottom organisms. The cage of sea bass established by CMFRI, Cochin was at a depth of 10 m in inshore area off Cochin.

Wind

The wind can determine the suitability of a particular site or area for cage fish culture through its influence on cage structures and caged stock. Of particular concerns are violent storms. But up to certain level, effects due to moderate winds can be profitable by the mixing of water. Maximum permissible wind limit is 30 – 40 km hr^{-1}. The wind velocity limit also emphasis the need of suitable season for marine cage culture when wind velocity is low. The cage culture of sea bass conducted by CMFRI, Cochin was during October – April in the open sea, at Munambam, off Cochin. In the Arabian sea, during June – August, the winds blow at their greatest strength and by September, the wind velocity decreases and by October – November, the wind starts blowing from north westerly to north easterly with comparatively low velocities.

Waves

Wind driven waves are propagated by the frictional drag of wind by the wind blowing across a stretch of water that transfers energy to the fluid. Wave size is determined by wind velocity, wind duration and the distance of open, unobstructed water across which the wind blows; and is also influenced by the waves present when the wind starts to blow. At the windward end, waves are poorly developed with small wave heights and short periods of oscillation.

However, waves develop with distance, reaching maximum size when they attain the same velocity as the wind. Wave height increases with wind velocity and wave energy increases proportionally with square of wave height. The maximum limit of wave height for working on floating cages is 1m.

Currents and tide

Good water exchange through cages is essential both for replenishment of oxygen and removal of waste metabolites. A weak and continuous current stream is favorable to bring oxygen and remove wastes in a cage. However excessive currents impose additional dynamic loadings damaging floating structures or cages, reduce the cage usable volume due to the deformations of the net and may adversely affect fish behavior. The limit for current velocity is with a minimum of 0.05 m S^{-1} to a maximum of 1 m S^{-1}.

In all except a few coastal regions of the world, tidal currents are the predominant source of surface water currents. Attractive forces exerted by the moon and sun on the Earth produce tidal waves. The crest and trough of the wave are termed high and low tide respectively, while the wave height is referred to as the tidal range. Associated with the rise and fall of the tide are the horizontal motions of water or tidal currents. Maximum current velocity occur at the middle of the rise (flood) and fall (ebb) ie., during the mid time between highest and lowest tide. For marine cage culture, limited tide amplitude (<1m) is preferred. Based on the tide table for the particular area of the coast, current velocity thus can be predicted in pre-monsoon and post-monsoon season during a cage culture period. But in monsoon, current velocity is unpredictable. Current velocity during monsoon is mainly influenced by littoral current, strong winds, wave effects and increased river discharge. Hence there is every chance that current velocity can exceed its permissible maximum limit prescribed for marine cage culture. Monsoon season is generally avoided for marine cage culture activity.

Substrate

The cage site substrate range from rocky to soft mud. Mud or rock bottom may cause difficulties for a safe and reliable anchorage for cage. A sandy or gravel bottom is generally looked for.

Water Quality Criteria

Temperature and salinity

Fish and other farmed organisms have no means of controlling body temperature, which changes with that of environment. A rise in temperature increases metabolic rate and causes a concomitant increase in oxygen consumption and activity as well as production of ammonia and carbon dioxide. Salinity is a measure of the amount of dissolved solids present in water and is usually expressed in parts per thousand. Its relevance to cage culture lies principally in its control of osmotic pressure, which greatly affects the ionic balance of aquatic animals. Rapidly fluctuating conditions of temperature and salinities are harmful for marine life cage culture. Seasonal changes are also to be taken care of during the culture period. For most tropical marine life aquaculture, a temperature of 26 - 28°C in early morning with no abrupt changes is considered as suitable. Similarly preferred salinity range is 25 – 40 ppt, evading abrupt changes.

Dissolved Oxygen

Dissolved oxygen is required by all higher marine organisms for the production of energy for essential functions such as digestion and assimilation of food, maintenance of osmotic balance and activity. Oxygen requirements vary with species, stage of development, size and are also influenced by environmental factors such as temperature. If the supply of oxygen deviates from the ideal feeding, food conversion, growth and health can be adversely affected. It is therefore important that good oxygen conditions prevail at a site.

During the day, there is a net production of oxygen, but at night, when photosynthesis stops, the algal community in water becomes a net oxygen consumer. Where there are large algal communities, super saturation of DO may occur during the day and sub saturation condition prevail at night, with late afternoon maxima and pre-dawn minima, stressing fish. The environmental conditions conducive to blooms usually occur during the warmer months in areas subject to high nutrient influxes. External sources such as sewage discharges and agricultural run off may be important contributors. However, a sudden upwelling of nutrient rich water from deeper layers of the water body during the break down of stratification may also stimulate blooms. Problems can occur when algal blooms die. During decomposition, microbial respiration may remove much or even the entire DO resulting in fish kills.

Benthic oxygen demand can cause de-oxygenation of the hypolimnion. Good mixing, water exchange and flushing by proper currents, tides and winds is a must in order to shun this situation. Marine sites which have good bottom current which disperse settling wastes are desirable. Preferred DO level for marine life culture is >6 mg l^{-1}.

pH

pH is a measure of hydrogen ion concentration of a solution. pH is important to aquatic life because extreme values of it can damage gill surfaces, leading to death and because it affects the toxicity of several common pollutants like ammonia and heavy metals.

The pH of sea water usually lies in the range 7.5 – 8.5. Sea water is also well buffered ie., comparatively resistant to changes in pH through the addition of alkaline or acidic compounds. Preferred pH for marine life culture is 7.8 – 8.4.

Turbidity

Total suspended solids

Turbidity refers to the decreased ability of water to transmit light caused by suspended particulate matter ranging in size from colloidal to coarse dispersions. Turbid conditions arise from organic or inorganic solids suspended in the water column as a result of soil erosion, mining wastes and other industrial effluents. Cage fish farms are themselves a source of suspended solids.

The quantity and quality of material suspended in water column at any particular moment is largely determined by water movement, which transports, fractionates and modifies solids. Large, dense particles are more easily settled than small, less dense particles. Water currents can also prevent particles from settling and re-suspend settled materials. Water chemistry and salinity in particular influences turbidity through its effect on flocculation and settling and is important in the transport of sediments.

High levels of suspended solids cause gill damage, inducing the gill epithelial tissues to proliferate and thicken. If damage is sufficiently severe, the fish will die. Turbidity levels less than 100 mg l^{-1} have little effect on most species. However, duration of exposure is important. Preferred range of dry suspended matter for marine life cage culture is <2 mg l^{-1}.

Color / Transparency

Part of the light (solar radiation) striking water does not penetrate the surface. A portion is reflected depending on the roughness of the water surface and the angle of radiation. As light passes through water, scattering and differential absorption by the water takes place. Turbidity and color in water may result from colloidal clay particles, from colloidal or dissolved organic matter or from an abundance of plankton. Secchi disk visibility can be taken as a measure of colour / transparency of the water in marine life cage culture. The Secchi disk is a weighted disk, 20 cm in diameter and painted in alternate black and white quadrants. The average of depths at which the disk disappears and reappears is the Secchi disk visibility. Optimum transparency expressed as Secchi disk visibility for marine culture is <5 m as yearly mean. Transparency is an important factor deciding light penetration and euphotic zone (the stratum of water receiving 1% or more of incident radiation, where, photosynthesis proceeds at rates exceeding respiration), affecting the primary productivity and oxygenation of the culture water.

Total inorganic nitrogen

Ammonia N

Ammonia is the most toxic form of inorganic N produced in water. The major source of ammonia in water is the direct excretion of ammonia by fish. It also originates from the mineralization of organic matter by heterotrophic bacteria and as a by product of nitrogen metabolism by most aquatic animals. Both ammonia (NH_3) and ammonium (NH_4^+) are toxic, but NH_3 is much more toxic than NH_4^+. Ammonia toxicity increases with the increase in pH and temperature.

The ammoniacal N content of water is an index of the degree of pllution. Its concentration in unpolluted water should never be more than 0.1 mg l^{-1} and below this level, healthy growth of fish is expected. Aquatic autotrophs rapidly utilize ammonium ions, thus naturally preventing it from reducing to toxic levels.

As ammonia concentration increases in water, ammonia excretion by fish decreases and levels of ammonia in blood and other tissues increase. This results in an elevation of blood pH and adverse effects on enzyme catalyzed reactions and membrane stability. High ammonia concentrations in water also affect the permeability of fish by water and reduce internal ion concentrations. Ammonia also increases oxygen consumption by tissues, damages gills and reduces the ability of blood to transport oxygen. Histological changes occur in kidneys, spleen, thyroid and blood of fish exposed to sub-lethal concentrations of ammonia. Chronic exposure to ammonia increases susceptibility to diseases and reduces growth. Preferred range of Ammonia N as (NH_4 + NH_3) for marine culture is < 0.1 mg l^{-1}.

Nitrite N

Nitrite originates as an intermediary product of nitrification of ammoniacal N by aerobic bacteria. Marine water has high concentration of calcium and chloride which tend to reduce nitrite toxicity.

Nitrate N

Nitrate is the end product of nitrification of ammoniacal nitrogen by aerobic autotrophs. Its presence can also be due to land drainage.

The total inorganic nitrogen for marine life culture is < 0.1 mg l^{-1}.

Total inorganic phosphorus

Phosphorus (P) is found in the form of inorganic and organic phosphates (PO_4) in natural waters. Inorganic phosphates include orthophosphate and polyphosphate while organic forms are those organically-bound phosphates. Phosphorous is a limiting nutrient needed for the growth of all plants - aquatic plants and algae alike. However, excess concentrations of P can result to algal blooms. The total inorganic phosphorus for marine life culture is < 0.015 mg l^{-1}.

COD (Chemical Oxygen Demand)

The COD of water represents the amount of oxygen required to oxidize all the organic matter, both biodegradable and non biodegradable by a strong chemical oxidant. Preferred Chemical Oxygen Demand for marine life culture is < 1 mg l^{-1}.

Chlorine

Both free and combined, residual available chlorine are extremely toxic to fish. The measurable concentrations of chlorine in water for marine life culture is <0.02 mg l^{-1}.

Heavy metals

They originate mainly from anthropogenic industrial pollution. The toxicity of heavy metals is related to the dissolved ionic form of the metal rather than total concentration of the metal.

Mercury

Mercury (Hg) is toxic to both aquatic life and humans. Inorganic form occurs naturally in rocks and soils. It is being transported to the surface water through erosion and weathering. However, higher concentrations can be found in areas near the industries. The most common sources are caustic soda, fossil fuel combustion, paint, pulp and paper, batteries, dental amalgam and bactericides.

Mercury remains in its inorganic form (which is less toxic) until the environment becomes favorable, *i.e.* low pH, low dissolved oxygen, and high organic matter where some of them are converted into methylmercury (the more toxic organic form). Methylmercury tends to accumulate in the fish tissue, thus making the fishes unsafe to eat.

The total mercury in water for marine life culture should be <0.05 mg l^{-1}.

Lead

Lead (Pb) comes from deposition of exhaust from vehicles in the atmosphere, batteries, waste from lead ore mines, lead smelters and sewage discharge. Its toxicity is dependent on pH level, hardness and alkalinity of the water. The toxic effect on fish is increased at lower pH level, low alkalinity and low solubility in hard water.

The lead in water for marine life culture should be <0.1 mg l^{-1}.

Copper

Copper enters the environment naturally through the weathering and solution of copper minerals and from anthropogenic sources. Anthropogenic sources of copper in the environment include corrosion of brass and copper pipes by acidic waters, industrial effluents and fallout, sewage effluents, and the use of copper compounds such as copper sulphate as aquatic algicides. Major industrial sources of copper include smelting and refining industries, copper wire mills, electroplating, metal finishing, coal burning, and iron and steel producing industries. Large quantities of copper can enter surface waters, particularly acidic mine drainage waters, as a result of metallurgical processes and mining operations.

The toxicity of copper to marine organisms in marine and estuarine environments is influenced by physical factors and chemical characteristics of the marine environment:

The copper in water for marine life culture should be <0.02 mg l^{-1}.

Pesticides

Pesticide refers to any chemical used to control unwanted non-pathogenic organisms, including insecticides, acaricides, herbicides, fungicides, algicides and rotenone (used in killing unwanted fish) (Svobodova, 1993). These chemicals are designed to be toxic and persistent, thus it is also of concern in aquaculture. It can affect the quality of the aquaculture product as well as the health of the fish and humans.

Pesticide can be split into seven main categories namely, inorganic, organophosphorous, carbamates, derivatives of phenoxyacetic acid, urea, pyridinium, and derivatives of triazine (Dojlido and Best, 1993). Among these, the chlorinated form is of particular concern due to its persistence and tendency to bioaccumulate in fish and shellfish. Some examples are dichloro-diphenyl-trichloro-ethane (DDT), aldrin, dieldrin, heptachlor, and chlordane. The most common sources are agricultural run-offs, effluents from pesticide industries and aquaculture farms.

The safe level of DDT group in water for marine life culture should be < 0.025 µg l^{-1}.

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Diseases of seabass in cage culture and control measures

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The cage culture of finfish, especially marine cage farming is becoming more popular because of the many economic advantages associated with it. Though, operationally this has a number of advantages, the practice is vulnerable to natural hazards and can be affected by occurrence of diseases. Disease outbreaks can occur more often when fish are raised under intensive culture conditions and can pose problems in cage culture. Increased production under high density can create conditions conducive to outbreaks of infectious diseases and an increase in prevalence of parasites. Infectious diseases in fish culture are not only augmented by waste pollution, but exacerbated by crowding, handling, temperature and biofouling. The most common fish disease in cages is vibriosis caused by *Vibrio* spp. Furthermore, abrasions cause fin and skin damage to cultured stocks. Occurrence of infection/disease may be minimized by selecting good sites, proper mooring and observance of optimal stocking densities and careful handling of stocks.

Disease monitoring

Monitoring of fish stock health is essential and early indications can often be surmised from changes in behaviour, especially during feeding. Some indication of disease status can be gained from examination of moribund fish netted from the cage surface. Rapid detection and removal of dead fish helps to prevent the spread of disease.

Diseases in Cage fish farming

The disease types and severity are greatly influenced by the species of fish, the conditions in which the animals are cultured and the husbandry management. Fish cultured in floating cages become particularly susceptible to disease when various environmental parameters such as temperature, salinity, dissolved oxygen and suspended particles fluctuate suddenly or widely, or following rough, although often unavoidable, handling operations. Once conditions suitable for pathological changes develop, progress to disease in the warm water environment is rapid. Early detection of behavioral changes and clinical signs in the cultured animals are critical for proper diagnosis of the disease. In addition to diseases caused by infectious agents, diseases and abnormalities due to environmental stresses and nutritional deficiencies have also been recognized, which can lead to secondary infections. Certain types of physical injury are specific to caged fish, *e.g.*, if over-stocked they may suffer from fin and skin damage caused by net abrasion and are susceptible to pathogenic organisms if handled without due care. Caged marine fish are vulnerable to "red boil disease" (*Vibrio anguillarum*) following routine handling operations at polluted sites (Chua and Teng, 1980).

Caged fish established in coastal environments may be exposed to a wide range of pathogens. From this perspective, the worst sites are those in which pathogenic or potentially pathogenic organisms exist prior to establishment of the farm and those in which disease organisms thrive following the installation of cages. Facultative pathogenic organisms are often associated with water bodies where a source of infection, such as untreated sewage, is present. There exists a link between trophic state and bacterial/fungal infections in fish. Chua (1979) observed that the ectoparasitic isopod *Nerocilia* sp. that attacked caged rabbit fish (*Siganus rivulatus*) was more prevalent in organically enriched waters.

Both wild fish populations and intermediate hosts in the life cycle of a fish parasite represent a risk for the fish farmer. Cages of salmon attract scavenging sathe (*Pollachius virens*) that often harbour the sea lice *Lepeophtheirus salmonis* and *Caligus elongatus,* and laboratory trials have clearly shown that lice can transfer between host species (Bruno and Stone, 1990). In the UK, caged fish were found severely infested with the cestodes, *Triaenophorus nodulosus* and *Diphyllobothrium* spp. resulting in heavy mortalities and the closure of at least one farm (Wootten, 1979; Jarrams *et al.*, 1980). The source of infection was subsequently traced to the wild fish populations.

Disease risks can be minimized by avoiding sites where a pre-development survey reveals parasites or disease agents to be present in the wild fish or intermediary hosts. However, problems may still occur through the introduction of diseased stock to the farm or the attraction of birds and other opportunistic predators. Epidemiological studies have revealed the importance of management in reducing the incidence of disease and mortality. A four year study of disease outbreaks in 11 Irish salmon farms showed that interruption of parasite life cycles through fallowing, the separation of year classes of fish to different sites and the practice of basic hygiene methods could significantly reduce the severity of disease outbreaks (Wheatley *et al.*, 1995).

Infectious diseases of cage cultured fish

Generally, infectious diseases of fish are caused by virus, bacteria, fungi and parasites.

Diseases caused by viruses

Viral diseases have not been considered to be a significant factor in marine and brackishwater culture. However, such disease as lymphocystis has recently become one of the problems in seabass culture. Viral diseases in cage cultured fish have been on the increase since the 1980's in East Asia and the 1990's on south-east Asia (Nakai, 1995). Virological research received a new impetus following the high mortality in hatchery-bred juvenile fish soon after being placed in sea cages. With the increasing awareness of virus-related diseases and with new species of fish being selected for culture, more reports of known and new viral diseases are to be expected.

Viral nervous necrosis (VNN)

VNN disease has been found in all warm water marine environments where marine fish have been cultured in cage environments, particularly in juvenile stages. The viral particles are packed in the cytoplasm of retinal and brain cells of affected fish. Infected fish exhibit whirling movements, lethargy, dark body colouration, loss of balance and hyper-excitability in response to noise and light. Mortalities are usually high and occur within a week of the onset of first signs. Extensive spongiosis is typically observed in the retina, brain and central nervous system. VNNV is an RNA virus and can be detected by RT-PCR. A PCR method based on the sequence of the virus coat protein genome (RNA2) was used to diagnose the virus in spawners, suggesting vertical transmission of the infection.

At present there is no known method of therapy, but vaccination using recombinant coat protein of live piscine nodavirus in sevenband grouper, *Epinephelus septemfasciatus*, resulted in significantly lower mortality in the virus challenge tests, indicating great potential for protection against the virus.

Iridoviral disease

Iridoviral disease has been reported in more than 20 marine species, from south-east and east Asia. Affected fish become lethargic and severely anaemic. The gills are hemorrhagic, the spleen is heypertrophic and the iridovirus appears in a crystalline array in the enlarged, basophilic splenic cells. Presumptive diagnosis based on Giemsa staining of histological sections can be confirmed by immunoflorescence or by PCR assay.

An experimental vaccine prepared by Nakajima *et al.* (1997) produced a higher survival in treated red seabream than in control group, suggesting the possibility of controlling the disease through vaccination.

Lymphocystis disease

Lymphocystis disease is commonly found in seabass raised in cages especially among juveniles. It has been observed at all temperatures in rather high salinity. Lymphocystis is a highly contagious infection and the disease follows a chronic course and, in general mortalities are limited. The infected fishes recover within a few weeks of the onset of the outbreak displaying little or no scar tissue. Although known to infect 30 families of marine fish, in south-east Asia, only Asian sea bass has been reported to be affected by this disease.

The disease is characterized by tumour-like masses of tissue on the body surface. These growths are clusters of extremely hypertrophic fibroblastic dermal cells. Occasionally internal organs can become infected. Diagnosis of lymphocystis disease is confirmed through histological sections and appropriate staining of the tissue lesions. The observation of the typical icosahedral virions by electron microscopy offers further confirmation. Horizontal transmission is the most probable route, facilitated by high stocking density and unfavorable environmental conditions. In south-east Asia, trash fish used as feed may be another source of infection. A decrease in stocking density and culling of visibly infected individuals are the only known measures that can be adopted to reduce the impact of the disease.

Diseases caused by bacteria

Many clinical signs of bacterial diseases of cultured marine fish are similar. Definitive diagnosis requires the isolation and *in vitro* culture of the organisms involved. A great number of aquatic bacteria are opportunistic and under normal environmental conditions do not cause disease, becoming pathogenic only when the balance of the host/environment is changed by elevated stocking densities, inadequate nutrition, deteriorating water quality, rough handling (*e.g.*, net changing, grading) and other stress factors.

Gram-negative bacteria

Vibriosis is the disease caused by a group of bacteria belonging to the family Vibrionaceae. Vibrios are ubiquitous in all marine environments and most are facultative pathogens. The infectious disease they cause is one of the most significant in mariculture. Diseases caused by *Vibrio* sp. typically appear as ulcerative haemorrhagic septecaemia. It occurs frequently during periods of fluctuations in salinity, increased organic load, or stress brought on by net changing and grading of fish. The period following initial stocking is particularly critical. The clinical signs are congestion and red boils appearing on the body surface and gradual darkening of the body. The petechial haemorrhages usually enlarge into irregular and deep lesions, which disintegrate the skin, exposing the underlying muscle, which becomes necrotic. The tissues surrounding the infected vent are usually reddened and inflamed. The body is completely covered by a thick layer of mucus. Internally, there is congestion and hemorrhage of the liver, spleen and kidney, frequently accompanied by the presence of necrotic lesions. The gut and particularly the rectum may be distended and filled with a clear viscous fluid.

The pathogenic vibrios which have been isolated from seabass include *Vibrio parahaemolyticus, V. anguillarum* and *V. alginolyticus*. Good husbandry practices and adequate nutrition are essential to prevent the development of vibriosis. Though in the initial stages the disease can be effectively treated with antibiotics, the use is not recommended due to the risk of development of resistant strains. Prophylactic measures such as vaccines are recommended.

Pasteurellosis – Photobacterium damsela

Pasteurellosis is an most important bacterial disease of cultured maine fish which is caused by the Gram-negative non-motile bacterium, *Photobacterium damsela*. This is a septicaemic disease with no external signs except occasional darkened spots on the body surface. A large number of white spots corresponding to foci of bacterial colonization engulfed by phagocytes are found in the spleen and kidney, and to a lesser extent in the liver. The diseased fish rapidly lose their vigour, sink to the bottom of the cage and die. Ampicillin and florfenicol have been reported to be effective when administered in feed. However, this bacterium is known to become resistant to antibiotics. Vaccine preparations also give satisfactory results.

Gliding bacterial disease/tail rot disease (Flexibacter sp.):

Tail rot disease caused by gliding bacteria of the genus *Flexibacter,* is one of the diseases commonly found in Asian seabass in cages. The bacteria first gain entry through damaged caudal fin, where the tissues are gradually eroded away by the bacteria. The bacteria then invade the muscular region, the muscles disintegrate and typical tail rot occurs. No pathological changes are normally observed in the internal organs. The disease usually affects seabass fry, 2 -3 weeks after their introduction sea cages.

It is difficult to prevent and control the disease in the cage environment. The standard treatment is feed medicated with oxytetracycline or a bath in sodium nifurstyrinate. However, the results are usually unsatisfactory. A combination of freshwater treatment and reduction of stocking density helps to reduce mortality in affected seabass.

Tenacibaculum maritimum (formerly *Flexibacter maritimus*) is reported as the etiological agent of flexibacteriosis disease in red seabream (*Pargus major*), European seabass, *Dicentrarchus labrax etc.*

Gram-positive bacteria

Streptococcosis

Streptococcosis caused by non-motile, gram-positive bacteria, *Streptococcus* sp. is most severe when farmed fish are stressed and water temperature is high. The onset of the disease is related to the rapid growth of the bacterium in the intestine where both extracellular and intracellular toxins are produced. The common clinical signs are darkening of the body, erratic swimming, hemorrhage in the intestine, liver, spleen, and kidney and abdominal distention. Necroses of the heart, gill, skin and eye have also been reported.

Confirmation of the diagnosis requires culturing of the pathogen, preferably on a blood-enriched medium. Control is mainly by chemotherapy. Antibiotic treatment with erythromycin and spiramycin has proved effective.

Mycobacteriosis

The etiological agents of mycobacteriosis, *Mycobacterium marinum* cause systemic, chronic infections in fish. The disease follows a chronic course and remains asymptomatic for a long time. Superficial ulcers and exophthalmia are often the only external signs. Spleen and kidney however are severely affected and are enlarged with granulomatous lesions that appear macroscopically as whitish nodules. In advanced cases these lesions spread to liver, heart, mesentery *etc.*

Nocardiosis

Nocardiosis is a chronic bacterial disease that affects both freshwater and marine fish. Many clinical characteristics of nocardiosis are similar to mycobacteriosis. Early signs of infection include anorexia, inactivity, skin discolouration and emaciation. In the late stages, nodular skin lesions may ulcerate or extend to skeletal muscle and visceral organs, causing abdominal distension. There is no effective therapy for this disease. The route of infection in fish is not known, but is probably through direct contact or contaminated food. Clean environment is an important factor in preventing the occurrence of the disease.

In addition to these more established pathogens, upcoming bacterial diseases potentially harmful for aquaculture species are being identified. A previously unrecognized disease namely "pot belly or big belly" disease caused by a facultative intracellular Gram-negative bacterium has been identified. Infections with this previously uncharacterized pathogen causes severe visceral granulomatous lesions in Asian sea bass fry < 5 g with an associated mortality rates of 70-80%.

Parasitic diseases

Parasitic protozoa

Protozoans are probably the most important group of animal parasites affecting fish. Many reports from all over the world indicate great losses in cage culture caused by protozoans. Environmental factors affect the susceptibility of fish to certain protozoa. Oxygen concentration and temperature are the factors affecting both hosts and parasites. Since many protozoans transfer from fish to fish through the water, fish population density is an important factor. Tremendous infestation of protozoans can occur in a relatively short time where fish populations are dense. Other factors such as host size, age, host specificity, immunity and the influences of host condition also play an important part in the host reaction to invasion by protozoa.

Protozoans cause harm to fish mainly by mechanical damage, secretion of toxic substance, occlusion of the blood vessels, depriving the host of nutrition and rendering the host more susceptible to secondary infections. Some of the most common clinical signs are changes in swimming habits such as loss of equilibrium, flushing or scraping, loss of appetite, abnormal colouration, tissue erosion, excess mucus production, haemorrhages and swollen body or distended eyes.

Cryptocaryon sp.

Cryptocaryon sp. is the marine counterpart of the freshwater *Ichthyophthirius* species and similarly cause the white spot diseases in marine fish. Its morphology and life cycle is quite similar to that of the "Ich". The surface of invaded fish reveals white pustules or numerous minute, greyish vesicles which are nests of cilliates burrowing under the epidermis. They feed on the host's cells underneath the epithelium and cause heavy irritation resulting in excessive production of mucus and finally completely destroying the fine respiratory platelets of the gill filaments. On the skin, this parasitic protozoan causes considerable lesions resulting in destruction of large areas of the epidermis. Secondary infection may complicate the situation and the host dies. The incidence of *Cryptocaryon* sp. in seabass showed a distinct peak during low water temperature period.

The presence of *C. irritans* in cage-cultured fish means that the cages are kept in too shallow waters. If logistically feasible, the cages should be moved in to an area where sufficient depth and currents prevent the theronts (free swimming infective stages) from re-infecting the fish.

Other important protozoan parazines affecting marine fish cultured in cages are *Trichodina* sp., *Brooklynella* sp., *Henneguya* sp. *etc.*

Parasitic helminthes

Worm diseases with the possible exception of those produced by monogenetic trematodes have not yet appeared to be a serious problem in seabass culture. This is probably due in large part to their complex life cycle and the difficulty in completing such cycles in the culture system. Helminthes parasites which have been found in seabass include monogenetic trematodes, digenetic trematodes, nematodes and acanthocephala.

Crustacean parasites

Crustaceans belonging to the Branchiura, Copepoda, Isopoda and Amphipoda are frequently found on the body surface and/or gills of caged marine fish.

Parasitic copepods

The parasitic copepods are among the most devastating of fish parasites. The mature female usually attaches to the fish and feeds on the host. After copulation the female matures and produces egg sacs while the male dies.

The only branchiuran reported is *Argulus* sp. Most of the copepods reported are caligids, which could cause epizootics in the farms. *Caligus* sp. has caused big problems in cultured seabass. They attach to the gills, buccal and opercular cavities, occasionally on the skin and fins of the seabass. Heavy infections can cause mass mortalities especially in young fish. *Lernanthropus* sp. are found attached to the gill of seabass especially in cage cultured fish. Large numbers of this parasite can cause anaemia to the fish host.

Parasitic isopods

Isopods which closely resemble *Aega* sp. have been found abundant in cage-cultured seabass. The parasite always attaches to the gills of its host. Clinical signs of infected seabass are as follows: fish lose appetite, become anemic and grow very slowly. Quick death can occur in 2–3 days in heavily infected young fish. *Nerocila* sp. and *Gnathia* sp. have also been reported in seabass.

Parasitic crustaceans are generally introduced along with fish caught in the wild for culture, but several of them are transmitted by wild fish around the cages. Prevention is therefore difficult.

In addition to the infectious causes, diseases and abnormalities due to environmental contaminants and nutritional deficiencies have been recognized as important problems in fish culture whenever diets as well as control or water quality become inadequate. Malnourishment or undernourishment of seabass under culture can result in slow growth, susceptibility to diseases or death.

In Asia, trash fish are widely used as feed in cage farming of marine finfish. Fry are often wild caught or derived from wild-caught broodstock. Furthermore, legislation for and implementation of farming licenses and zoning policies are not in place in most Asian countries. Coupled with a 'gold rush' mentality, this often results in too many fish and too many farms in a concentrated area, which in turn promotes disease transmission. The combination of all these factors, together with the diversity of organisms in tropical waters, leads to a truly challenging disease situation.

Furthermore, irresponsible use of antibiotics and chemicals for disease control in aquaculture can lead to residue problems, an increasing consumer concern, and to the development of drug resistance among the bacterial pathogens. In addition to developing antibiotic resistance, sick fish often do not eat and the efficiency of delivering antibiotics orally is often questionable. The use of antibiotics is a curative measure to treat an existing infection; in contrast, vaccination is a preventative measure, dependent on the immune system of the animal. Vaccines can act against bacterial, viral and, at least experimentally, parasitic infections and they will usually act only against the targeted pathogens. In Asia, with the exception of Japan, few fish vaccines are yet commercially available. The major advantages of prophylactic vaccination over therapeutic treatment are that vaccines provide long-lasting protection and leave no problematic residues in the product or environment.

Asian aquaculture will continue to grow at a fast pace due to both area expansion and production intensification. Under these conditions, the prevalence and spread of infectious diseases will unavoidably increase as a result of higher infection pressure, deterioration of environmental conditions and movement of aquatic animals. Accordingly, the effective control of infectious diseases has become more and more important in the cultivation of aquatic animals. Good health management is the best way for disease control. Collectively, this includes the use of healthy fry, quarantine measures, optimized feeding, good husbandry techniques, disease monitoring (surveillance and reporting), and sanitation as well as vaccination, and biosecurity measures when diseases do occur. Overall, the emphasis must be on prevention rather than treatment.

Open sea cage culture in India- A sociological perspective

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Introduction

Marine cage culture is the latest innovation in Indian mariculture scenario. The first cage was demonstrated in Visakhapatanam in 2007-08. The logic of the floating cage culture technology is the conversion of marine space into a controlled production system. This entails a number of socio-political issues apart from the technological ones. Prominent among them is the changing context of marine tenure in the country. This paper analyses such issues based on a preliminary study conducted in some of the locations where the cage demonstration has been implemented. The major sociological framework employed in the analysis is that of the Actor –Network Theory (ANT) proposed by Latour (2007). Thus the methodological objective was to explore the actor- networks at different locations using participatory protocols.

The idea of cultivating fish in the open sea through cages is of recent origin. Open sea cage culture is being posed as an answer to increasing demand for food in the context of the declining yield trend shown by capture fisheries (especially when the Chinese catch excluded) and the problems faced by the land based – aqua farming technology. The pioneers in this technology are countries like Norway, Japan and USA. After about three decades of intense research and development activities cage culture has become a mature industry in these countries (Grottum and Beveridge 2007). In the Asian region, China has attained significant strides in off shore cage culture. Within the span of a decade (1990-2000) and with an investment of more than US$10 million, China has deployed about 4000 such cages yielding about 2 lakh tons (Chen and Chen 2008).

India's entry into the arena of off shore cage culture is very recent and this marks a significant milestone in the mariculture pursuits of the country. The history of mariculture research in India dates back to early seventies when pioneering attempts were made by CMFRI to farm mussels in the inshore waters using lines. Though the technology was successfully demonstrated, it did not capture the imagination of the fisher folk for reasons obvious. The major stumbling block was the absence of a "culture mindset" which was partly due to resource abundance amenable to exploitation through capture fisheries. With the capture fisheries production leveling off in the recent years the potential for the open sea cage culture is huge. The success demonstrated at Visakhapatanam has come as a shot in the arm to our mariculture aspirations.

Objective and methodology

It is in this context that the present study was undertaken to assess the perception of the stakeholder constituency and to reflect on the challenges and prospects of open sea mariculture. The cage culture is a newly introduced innovation and could be either adopted or rejected by the stakeholders. An individual's decision to adopt or reject a new practice passes through several stages, and does not happen at once. Innovation diffusion studies have recognized the adoption/non-adoption of a new introduced practice is influenced by whether or not it matches with the adopters' needs, situation, and perceptions of the innovation (Rogers, 2003).The rate of adoption might differ among individuals depending on his/her level of innovativeness. The more innovative an individual the shorter is the adoption time. Since the innovation is in the nascent stage of adoption it is not possible to draw of picture of its diffusion. The perception of people on the probability of its adoption, which is mainly determined by innovation characteristics (as defined by Rogers, 2003) only can be assessed now.

The location of the sites where the preliminary study was conducted is depicted in Table1. It also shows the current status of the culture in these sites. As it can be seen some of the sites one demonstration was over and in other places the first series of demonstration was in different stages of operation. There was continuous access to all the operations at Munambam which was covered during (9/12/08 to 18/04/09).

A notable feature of the innovation transfer model being attempted across the sites is the way in which the various agencies and institutions are integrated. The dominant mode is that of Public-Private Partnership. The table below gives an over all view on this aspect.

Table 1 Sites of open sea cage culture visited

Site	State,district	Distance from cmfri centre	Status of cage	remarks
1. ChaumukhBaliapal	Orissa, Baleswar/ Balasore	From Viskah, about 700km	Cage installed in the sea, 4000 fingerlings of sea bass stocked	Very good cooperation from the fisheries department and the fisher folk
2.Visakhapatanam	AP, Visakah	About 5km	Second cage *P monodon* stocked	The fishermen group has gained more confidence
3.Iskapalli	AP, Nellore	About 200 km from Chennai	-Two cages installed- Modifications done to stock *P. monodon* and lobsters	Fisher folk evince keen interest
4.Pulikat	Tamil Nadu,	About 50 km from Chennai	Ready for stocking lobsters Good support from the	NGO and fisher folk. Fishers more interested as this is the second time
5.Munambam	Kerala	About 30 km from Kochi	Harvest done	Pre mature harvest due to drifting of cages; growth parameters promising
6.Vizhinjam	Kerala	About 18 km from Thiruvananthapuram		Harvest done

Table 2 Modes of institutional arrangements

Site	Mode	Details
ChaumukhBaliapal(orissa)	PPP	Society of the traditional fisherfolk+State Department of Fisheries+CMFRI+NFDB
Visakhapatanam (AP)	do	Fishermen society +lead role by a fisherman leader+DF+CMFRI+NFDB
Iskapalli,Nellore(AP)	do	Fishermen society +lead role by a fisherman leader + DF+ CMFRI+ NFDB
Pulikat, Chennai (TN)	do	Fishermen society +NGO +DF+CMFRI+NFDB
Munambam		Fishermen group +CMFRI+NFDB
Vizhinjam		do

Perception of stakeholders

Perceived attributes of an innovation such as relative advantage, complexity, compatibility, trialability, and perceived risks have been used extensively in previous innovation studies to evaluate innovation adoption. (Rogers 1983) defines relative advantage as 'the degree to which an innovation is perceived as being better than the idea it supersedes'. Complexity is defined as 'the degree to which an innovation is perceived as relatively difficult to understand and use']. Trialability is defined as 'the degree to which an innovation may be experimented with, on a limited basis' Compatibility is defined as 'the degree to which an innovation is perceived as consistent with the existing values, past experiences, and needs of potential adopter'. Perceived risk is defined as the degree to which an innovation is perceived to be economically risky.

The stakeholders in general showed enthusiasm towards the innovation in all the locations. Though this is encouraging it needs to be qualified with the facts that the demonstrations are being carried with financial support to the stakeholders. But the real litmus test is their willingness to adopt the innovation entirely on their own. When this question was asked on a Likert type scale the responses obtained were revealing. The * sign indicates the perception before the demonstration and $ indicates the same after the demonstration. Visakahpatanam was found to be more positive on this count.

Table 3 Perceived adoptability across locations

	1(Blsr)	2(vsk)	3(nlr)	4(plkt)	5(mnmbm)	6(vzj)
High		$				
Medium	*	*		$	$	$
Low			*	*	*	*

(High-above 75% of response, Medium-50-75% Low –below 50%)

Though high initial cost is a perceived deterrent across the locations, the Visakhapatanam group was optimistic to get financial assistance through the Tsunami assistance fund of the Government. In Balasore, the group was willing to put operational expenditure provided the cage was given to them.

It is to be noted that the demonstration is just in progress in Balasore. Nevertheless the stakeholders here have a much more favorable perception towards the innovation. This could be because of certain socioeconomic peculiarities of the village like backwardness, homogeneity of the group, and the presence of a culture mindset owing to the fact that almost all the fishermen families possess farm lands for cultivation. The fishermen in the west coast (represented by two sites) was found to be a bit reserved as only medium response was obtained on this count. This must be read in tandem with their perception on innovation characteristics which was found to be low on

Another remarkable observation is the increase in level of confidence shown by the fisherfolk after the demonstration of the technology in one season.

When the perceived innovation characteristics were considered the pattern obtained has been deputed below. The response was not collected from the two places where the demonstration was not completed. The innovation characteristics registered a better perception in Visakhapatanam. This could be due to many facts like

a) the positive impact due to the success of the first demonstration
b) the role played by Mr Polanna who happen to be the leader of a state level fishermen association
c) better accessibility to technical advise and supervision from CMFRI
d) higher innovativeness of the group

Table 4 Perceived innovation characteristics

Innovation characteristic	1(Blsr)	2(Vsk)	3(Nlr)	4(Plkt)	5(Mbm)	6(Vzj)
Relative advantage (high)		$$$		$	$	$
Complexity (low)		$$		$	$	$
Trialability (high)		$$$		$$	$	$
Compatibility (high)		$$$		$$	$	$
Perceived risk(low)		$$		$	$	$

($$$-above 75% Agree, $$-50-75% Agree,$-less than 50% agree)

Prospects and Challenges

Though it is too early to comment on the future of the innovation in the Indian scenario some reflections made in this direction seems not to be out of place. The question is will the technology get adopted and diffused? The answer depends on three major factors a) technological b) socio-economical and c) political/governance. Since the technological factors are being addressed by the concerned persons I limit my discussion to the sociological and political aspects here.

Sociological factors

The major factor that influences the innovation decision process is the extent to which the candidate innovation meets the felt needs of the incumbent adopter. The relative advantage of this innovation has been favouarbly perceived. The fisher folk in general feel that the capture fisheries sustainability is in peril and they are in the look out for alternative livelihood sources. It can be assumed that the cage culture in this aspect has captured their imagination if one goes by the enthusiasm shown by the people. The emergence of a culture mindset is a welcome sign because fishermen are believed to be still in the hunter- gather mindset.

There are push and pull factors behind the adoption of any innovation. One of the major deterrents is the perceived high initial cost. But if the cages are made available to the fishermen group at a subsidized cost it is well likely to be adopted. Attention needs to be given to cost cutting strategies in the cage fabrication. The cost of HDPE cages in China is said to be only Rs600/cubic meter. Another factor is the price they get for the cage-cultured fish. Though high value fishes are being recommended now, their price is dependent on the market vulnerability. Another factor is the delay in the financial reward. Unlike capture they have to wait for about five to six months for the harvest. But compared to the former, cage culture is less risk prone. But fishermen were of the opinion that if the season of the culture is planned in such a way that the harvest synchronizes with the lean season/high demand season like festivals they could earn better price. Since cage culture offers control over the production system possibilities of getting premium price by way of organic certification or other certifications could be explored.

Though threats like poaching or community-agreed vandalism are real they can be remedied if the community is vested with the ownership of the cages. Innovativeness of the fisherfolk need to be tapped to the maximum extent possible in all the aspects like selection of sites, species, feed, cost cutting strategies *etc.*

Political/governance factors

The cage culture being a point of departure against the conventional sense of marine tenure it poses many challenges in this regard. To established ocean users cage culture is a new system of property that regulates access and usage of marine resources. Until recently the ocean was considered to be the last of the commons, where ownership is based on the labour that fishermen invested in the act of catching them. The marine tenure system prevalent in the country, though its enforcement is feeble, grant rights to fishing territories they do not guarantee that fish would not migrate out of these territories. Until a fish is caught nobody is considered to be a legitimate owner of that fish. The concept of cage culture thus marks a significant departure from this notion. So the need of the hour is to chalk out a suitable marine property rights policy giving due weightage to the rights of the community but not forestalling socially committed corporate bodies in entering the scenario on a Public Private Partnership mode. A system of Public hearing as has been practiced in Hawai (Suryanata and Umento 2002) could be followed in legitimizing commercialization of marine space.

Cage as a new metaphor

There is nothing more puzzling than a proposition that views Open Sea Cages as bridges! But this is the concluding remark I would like to pose. Yes, the cages have started acting as socio-psychological bridges between the marine fisheries R&D and the fisherfolk along the coast of this country. The Indian coastal villages never had such a "bridge' built through their collective psyche, except perhaps the few mariculture interventions done in the late seventies. There always has been an intangible barrier between the fishermen and the kind of scientific knowledge, (especially the stock assessment knowledge which is the main mandate of CMFRI) that has been generated by the researchers. Being relevant only at a wider policy level, there is no wonder that, this knowledge base could hardy capture the imagination of the fisherfolk. They often found the research system as an anathema, informing governments to make policies that went against their immediate interests (like mesh size regulations/ reduction in fishing effort/even the seasonal fishing bans). The scientific advice was deemed to be with a touch of inherent negativity. This has led to the development of an annoying sense of mistrust among the fisherfolk and this has been the biggest communication barrier an extension scientist working in the marine sector has to surmount. No social scientist who has ever experienced the frustrating pangs of establishing a "connection " with the fisherfolk can fail to see the transformation of cages, with its positive image of being a tangible production system innovation, as becoming emotional bridges.

Concluding remarks

It is too early to predict the future of the cage culture in India. The innovation has many challenges as well as opportunities. To tackle the challenges a great deal of discussion, planning and coordination is required to create dynamic networks on a value chain basis. However its fate lies in the collective will, social capital and institutional capacity of a number of agencies and institutions involved. The lessons from the countries who are ahead of us could be of much use in terms of not only the technology but also the marine farming governance. The demonstrations being undertaken in different parts of the country needs to be viewed in the perspective of Multi Locational Trials and there is an urgent need to convert such collective knowledge into location specific policies, norms, networks and practices.

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Grow out culture of seabass in cages

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Aquaculture of *Lates calcarifer*, known as seabass, was commenced in the 1970s in Thailand, and rapidly spread throughout Southeast Asia. In India also it is a sought after fish in many states. The grow-out phase involves the rearing of the seabass from juvenile to marketable size. Marketable size requirement of seabass vary country to country *e.g.* in Malaysia, Thailand, Hong Kong and Singapore, the normally accepted marketable size of seabass is between 700–1200 g while in the Philippines, marketable size is between 300–400 g. The culture period in grow-out phase also vary from 3–4 months (to produce 300–400) to 8–12 months. The success of marine cage culture of seabass and its economical viability have contributed significantly to large scale development of this aquaculture system

Among the attributes that make Seabass an ideal candidate for aquaculture are:

- It is a relatively hardy species that tolerates crowding and has wide physiological tolerances.
- The high fecundity of female fish provides plenty of material for hatchery production of seed.
- Hatchery production of seed is relatively simple.
- Seabass feed well on pelleted diets, and juveniles are easy to wean to pellets.
- Seabass grow rapidly, reaching a harvestable size (350 g – 3 kg) in six months to two years.

Today Seabass is farmed throughout most of its range, with most production in Southeast Asia, generally from small coastal cage farms. Often these farms will culture a mixture of species, including Seabass, groupers (Family Serranidae, Subfamily Epinephelinae) and snappers (Family Lutjanidae). Australia is experiencing the development of large-scale Seabass farms that reflect the industrialized style of aquaculture seen in Europe, where Seabass farming is undertaken outside the tropics, recirculation production systems are often used (*e.g.* in southern Australia and in the north-eastern United States of America).

Most seabass grow out is undertaken in net cages. The cages are either floating or fixed and range in size from 3 x 3 m up to 10 x 10 m and 2 -3 m deep. The mesh sizes of these cages ranges from 2-8 cm. Seabass are reared from juvenile to marketable size varies depending on water quality and the environmental conditions of the culture site. Floating cages can be stocked more than stationary cages. This is because floating cages are usually set in sites with better aquatic environmental conditions such as deeper water, smaller fluctuation of water salinity, more rapid circulation and further away from sources of pollution.

Suitable site for seabass cage culture

Criteria for selecting a suitable site for cage culture of seabass include:

a. Protection from strong wind and waves. The cage culture site should preferably be located in protected bays, lagoons, sheltered coves or inland sea.

b. Water circulation. The site should preferably be located in an area where influence of tidal fluctuation is not pronounced. Avoid installing cages where the current velocity is strong.

c. Salinity. Suitable site for seabass culture should have a salinity ranging from 13–30 ppt.

d. Biofouling. The site should be far from the area where biofoulers abound.

e. Water quality. The site should be far from the sources of domestic, industrial and agricultural pollution and other environmental hazards.

The optimum temperature for Seabass culture is 28°C, with acceptable growth rates between 26-30°C. Temperatures below this range will result in decreased metabolism and growth. Seabass generally stop feeding at temperatures below 20°C. At optimum temperatures, Seabass can be raised to market size (500g) between 6-12 months.

The water quality parameters which are considered of minimum range for cage culture of seabass

The suitable water quality for cage culture of seabass.

Parameters	Ranges
pH	7.5–8.3
Dissolved Oxygen	4.0 – 8.0 mg/L.
Water salinity	10 – 31 ppt.
Water temperature	26 – 32 °c
Ammonia — nitrogen	less than 0.02 mg/L.
Hydrogen sulfide	none

The stocking densities used for cage culture generally range from 15 to 40 kg/m^3, although densities may be as high as 60 kg/m^3. Prior to stocking seabass juvenile in cages, fish should be acclimatized to the ambient temperature and salinity prevailing in the cages. The fish should be graded into several size groups and stocked in separate cages. The stocking time should be done in the early mornings (0600–0800 hours) or late in the evening (2000–2200 hours) when the temperature is cooler.

Stocking density in cages is usually between 40–50 fish per cubic meter. Two to three months thereafter, when the fish have attained a weight between 150–200 g, the stocking density should be reduced to 10–20 fish per cubic meter. Generally, increase in densities results in decreased growth rates. Higher stocking densities require more monitoring of water quality and fish health, additional aeration and higher water exchange rates.

There should be spare cages as these are necessary for transfer of stock and to effect immediate change of net in the previously stocked cage once it has become clogged with fouling organisms. Changing cages allows for grading and controlling stock density.

The choice of netting mesh size of fish

Mesh size	Size of fish
0.5 cm	1–2 cm
1 cm	5–10 cm
2 cm	20–30 cm
4 cm	bigger than 25 cm

Feeds and feeding

Due to the carnivorous nature of Seabass, a high protein diet is required for efficient growth. Commercial diets are readily available from a number of feed manufacturers and are generally produced in a floating or sinking pellet. Food conversion ratios (FCRs) for Seabass should be in the range of 1.5-2:1 (kg of food: kg of weight growth), however lower FCRs have been reported by some industry members.

Trash fish is the main feed for seabass culture. Trash fish should be fresh and clean. Trash fish used in Thailand are sardines and other small marine fish. The trash fish should be chopped and fed twice a day, in the morning and afternoon. The size must be suitable for the size of the mouth of the fish. The farmers should give the feed slowly and watch the fish. Feeding should be stopped when the fish no longer come up to the surface; it shows that the amount of feed is enough for them.

Feed is the major constraint confronting the seabass culture industry. At present, trash fish is the only known feed stuff used in seabass culture. Chopped trash fish are given twice daily in the morning at 0800 hours and afternoon at 1700 hours at the overall rate of 10% of total biomass in the first two months of culture. After two months, feeding is reduced to once daily and given in the afternoon at the rate of 5% of the total biomass. Food should be given only when the fish swim near the surface to eat. Vitamin premix may be added to the trash fish at a rate of 2 percent, or rice bran or broken rice may be added to increase the bulk of the feed at minimal cost. Food conversion ratios (FCRs) for Seabass fed on trash fish are high, generally ranging from 4:1 to 8:1.

Growth

Growth is highly variable and depends on various factors including temperature, feeding rate, feed quality and stocking density. Generally fish grows from fingerling to 300-500g in 6-12 months and to 3kg in 2 years.

Stocking larger size seed fish attains greater individual and total weight per cage than smaller ones. Seabass size ranges from 10-17cm in length are suitable for culturing in cages with grow out at 6- 7 months.

Monthly growth (g) of seabass at different stocking densities in cages (Sakaras, 1982)

Culture Period	Stocking density		
	16/m	24/m	32/m
0	67.8	67.8	67.8
1	132.3	137.5	139.2
2	225.2	229.1	225.5
3	262.9	267.5	264.1
4	326.2	332.0	311.5
5	381.1	384.9	358.8
6	498.6	487.1	455.4

Main problem in grow out culture are feeding and prevention of cannibalism in young fishes. In order to reduce losses due to cannibalism, grow out is performed in two phases, viz. nursery phase up to a size of 20g in nursery ponds/cages and grow out phase The size of the feed must be suitable for the size of the mouth of the fish. The farmers should feed fish slowly and watch them. Feeding should be stopped when the fish no longer come up to the surface which indicates that the amount of feed is enough for them. Food conversion rates of seabass also depend on the quality and quantity of trash fish. Normally, seabass can grow at an average of I kg/yr. Survival rates for marketable fish culture are about 80-95 percent in normal culture conditions.

Open sea Cage culture: carrying capacity and stocking in the grow out system

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Developing open sea cage farming is a new way of providing employment to fishermen transferring from fish capture to aquaculture. It will also create significant socio-economic influences in the future. The near target of cage culture is that marine fish farming will become a main force in aquaculture sector. The open sea cage culture has been expanding in recent years on a global basis and it is viewed by many stakeholders in the industry as the aquaculture system of the millennium. The Asian seabass, *Lates calcarifer,* known as "Kaalangi" in Kerala is an important candidate finfish species for sea cage farming.

Carrying capacity

A major consideration in the site selection process should be the carrying capacity of the site which indicates the maximum level of production that a site might be expected to sustain. Intensive cage fish farming results in the production of wastes which can stimulate productivity and alter the abiotic and biotic caracteristics of the water body, whilst less intensive methods can result in over croppping of algae and a fall in productivity. Hence profitability or even viability may be seriously affected. Therfore it is extremely important for all concerned with cage fish farming to have an accurate evaluation of the sustainbale levels of production at a particular site before culture.

The *carrying capacity* of a biological species in an environment is the population size of the species that the environment can sustain indefinitely, given the food, habitat, water and other necessities available in the environment. In ecological terms, the carrying capacity of an ecosystem is the size of the population that can be supported indefinitely upon the available resources and services of that ecosystem. Living within the limits of an ecosystem depends on three factors:

- the amount of resources available in the ecosystem
- the size of the population, and
- the amount of resources each individual is consuming.

A simple example of carrying capacity is the number of people who could survive in a lifeboat after a shipwreck. Their survival depends on how much food and water they have, how much each person eats and drinks each day, and how many days they are afloat. If the lifeboat made it to an island, how long the people survived would depend upon the food and water supply on the island and how wisely they used it. A small desert island will support far fewer people than a large continent with abundant water and good soil for growing crops. In this example, food and water are the natural capital of the island. Living within the carrying capacity means using those supplies no faster than they are replenished by the island's environment: using the 'interest' income of the natural capital. A community that is living off the interest of its community capital is living within the carrying capacity. A community that is degrading or destroying the ecosystem on which it depends is using up its community capital and is living unsustainably. So, in the context of sustainability, carrying capacity is the size of the population that can be supported indefinitely upon the available resources and services of supporting natural, social, human, and built capital.

Within the context of aquaculture, environmental carrying capacity is defined as the maximum number of animals or biomass that can be supported by a given ecosystem for a given time. This is particularly important to aquaculturists who seek to optimize the economic value or yield per unit area, or regulatory authorities who are interested in minimizing the negative impacts aquaculture can have on the natural environment through the issuing of permits or granting concessions.

Estimation of Carrying capacity

In semi-intensive and intensive systems the number of fish that may be stocked will be limited by the "carrying capacity" of the water. This can be calculated using standard methodology. Before considering how to model the impact of cage fish culture on the environment, the rationale behind using this method to increase fish production should be understood. The modeling is based on the assumptions that algal population densities are negatively correlated with water quality in general and growth and survival of fish stocks in particular, and that phosphorus (P) is the limiting nutrient which controls phytoplankton abundance in the water bodies. Phosphorus and, occasionally, light are the principal factors limiting production, and thus the net addition or uptake of P or materials which greatly influence the light climate will alter productivity. Phosphorus is an essential element required by all fish for normal growth and bone development, maintenance of acid-base regulation, and lipid and carbohydrate metabolism. Diets deficient in P can suppress appetite, normal food conversion and growth, and under extreme circumstances affect bone formation and lead to death.

Feed losses are inevitable during fish culture for a number of reasons; but the left over food that is not be eaten is actually not a loss in the culture systems; instead contribute to the wastes from the operation. Manufacturers estimate that 2% of feed is 'dust', due largely to the crumbling of pellets during packing and transport and thus at least 2% of commercial feeds will be uneaten and contributes to the water body.

In order to determine the potential of a water body for intensive enclosure, the productivity of the same prior to exploitation must be assessed through measurement of the steady-state total-P concentration, The development capacity of a lake or reservoir for intensive cage and pen culture is the difference between the productivity of the water body prior to exploitation, and the final desired level of productivity. As stated above, [P] can be used as a productivity indicator. However, it must be decided whether it is then mean annual algal biomass, or the peak annual algal biomass, as measured by chlorophyll levels [ch1] and $[ch1]^{max}$ respectively, that we wish to predict. Since fish are usually held in cages throughout the year, it is the latter parameter which should be considered.

The capacity of a water body for intensive cage and pen fish culture is the difference, Ä [P], between [P] prior to exploitation, $[P]_i$, and the desired/acceptable [P] once fish culture is established, $[P]_f$.

I.e. Ä [P] = $[P]_f - [P]_i$

Ä[P] is related to P loadings from fish enclosures, L_{fish}, the size of the lake, A, its flushing rate, ñ, and the ability of the water body to handle the loadings (*i.e.* the fraction of L_{fish} retained by the sediments, R_{fish}):-

$$\Delta[P] \quad \frac{L_{fish}\ (1-R_{fish})}{\bar{z}\rho}$$

$$L_{fish} = \frac{\Delta[P]\bar{z}\rho}{1-R_{fish}}$$

The acceptable/desirable change in [P], Ä [P] (mg m^{-3}), is determined as described above, and z can be calculated from hydrographic data obtained either from literature or survey work:-

$z = \frac{V}{A}$ Where V = volume of water body (m^3) and A = surface area (m^2) the flushing rate, (y^{-1}) is equal to Q_o/V, where Q_o is the average total volume out flowing each year. Q_o can be calculated by direct measurement of outflows, or in some circumstances can be determined from published data on total long-term average inflows from catchment area surface runoff (Ad.r), precipitation (Pr) and evaporation (Ev), such that

Q_o = Ad.r + A(Pr - Ev) (see Dillon and Rigler, 1975, for further details).

The retention coefficient, R, can be determined experimentally by measuring the mean annual inflow and outflow [P], $[P]_i$; and $[P]_o$ respectively:-

$$R = 1 - \frac{[P]_o}{[P]_i}$$

Marine cage aquaculture produces a large amount of waste that is released directly into the environment. To effectively manage the mariculture environment, it is important to determine the carrying capacity of an aquaculture area. In many Asian countries trash fish is dominantly used in marine cage aquaculture, which contains more water than pellet feed. The traditional nutrient loading analysis is for pellet feed not for trash fish feed. So, a more critical analysis is necessary in trash fish feed culturing areas. Based on the hydrodynamic model and the mass transport model in Xiangshan Harbor, the relationship between the water quality and the waste discharged from cage aquaculture has been determined. Here corresponding to FCR (feed conversion ratio), dry feed conversion ratio (DFCR) was used to analyze the nutrient loadings from marine cage aquaculture where trash fish is used. The environmental carrying capacity of the aquaculture sea area can be calculated by applying the models noted above. Here nitrogen and phosphorus are the water quality parameters considered for the calculation of carrying capacity. The simulated results showed the maximum nitrogen and phosphorus concentrations were 0.216 mg/L and 0.039 mg/L, respectively. In most of the sea area, the nutrient concentrations were higher than the water quality standards. The calculated environmental carrying capacity of nitrogen and phosphorus in Xiangshan Harbor were 1,107.37 t/yr and 134.35 t/yr, respectively. The results showed that the waste generated from cage culturing in 2000 has already exceeded the environmental carrying capacity.

Unconsumed feed has been identified as the most important origin of all pollutants in cage culturing systems. It suggests the importance of increasing the feed utilization and improving the feed composition on the basis of nutrient requirement. For the sustainable development of the aquaculture industry, it is an effective management measure to keep the stocking density and pollution loadings below the environmental carrying capacity. The DFCR-based nutrient loadings analysis indicates, in trash fish feed culturing areas, that it is more critical and has been proved to be a valuable loading calculation method. The modeling approach for Xiangshan Harbor presented here is a cost-effective method for assessing the environmental impact and determining the capacity. Carrying capacity information can give scientific suggestions for the sustainable management of aquaculture environments. It has been proved that numerical models were convenient tools to predict the environmental carrying capacity. The development of models coupled with dynamic and aquaculture ecology is a requirement of further research. Such models can also be useful in monitoring the ecological impacts caused by mariculture activities.

Fish stocking in the cages

The minimum recommended stocking density for common carp, tilapia, and catfish is 80 fish/m^3. A recommended maximum stock density for beginning farmers is the number of fish that will collectively weigh 150 kg/m3 when the fish reach a predetermined harvest size (Schmittou, 1991). The smallest recommended fingerling size for stocking is 15 g. A 15-g fish will be retained by a 13-mm bar mesh net. Larger fish can also be stocked into cages. Survival rates in well-placed and well-managed cages are typically 98 to 100 %. Unless greater mortality is expected, no adjustment is needed to calculate stocking density. An example of how to calculate the number of fish to stock per cage follows: Assume that a farmer wants harvest fish weighing 500 g from a 1m^3 cage.

Total fish weight at harves	t= 150 kg/m^3
Number to stock	= 300 fish (300 x0.5kg)
Desired average fish weight	= 0.5 kg at harvest
Production	= 150 kg/m^3

For a harvest of fish averaging 200 g, the number of fish to stock would be:

Number to stock	= 750 fish/m^3
0.2 kg x 750	= 300 kg/m^3

The carrying capacity of a body of water limits the weight of fish that can be cultured. Stocking so many fish that the carrying capacity is exceeded will result in increased stress, disease, and mortality, and reduced feed conversion efficiency, growth rate, and profit. Generally, 1,000 m^2 of water surface area is needed to support 400 kg of fish. A calculation can be used to determine the maximum number of fish which can be stocked into a cage(s) to assure that the weight does not reach the carrying capacity of the water body during culture.

Maximum volume of cages (m^3)	= 2.6a*
Where: a	= total surface area of water body (1,000s of m^2)

* The constant 2.6 is derived below

$$\frac{\dfrac{400 \text{ kg}}{1{,}000 \text{ m}^2 \text{ pond}}}{\dfrac{150 \text{ kg}}{\text{m}^3 \text{ cage}}}$$

Grow out of the sea bass culture starts as it transfers to the cages from the nurseries. Juveniles of sea bass reared in the nurseries of size 10 - 15 cm in length (25 – 50 g in wt) can be transferred to the cage for the grow-out. The stocking density in the cages varies from 20 – 25 kg/m^3 in the final harvest time. So with a final weight of expectation of 1 kg fishes in harvest time after a period of 6 – 8 months; from the cages the stocking density varies from 25 – 30 fishes / m^3 for the sea bass. Care must be taken to avoid handling stress and other physiological stresses as maximum as possible while transport and stocking.

Once when the carrying capacity is determined in a culture system, and optimum stocking is done accordingly, open sea cage culture can be a successful alternative for any species of high value marine fish.

Growth in fleet size and investment in marine fisheries and scope for open sea mariculture

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Fishing has been considered as a primary livelihood option since time immemorial, for the occupants of the coastal belt in India, stretching along 8129 kms. Fisheries play a predominant strategic role in the economic activity of our country by its contribution to national income, food and employment. It supports the deprived coastal community and serves as an important foreign exchange earner contributing substantially to food and nutritional security. It is also a principal source of livelihood to people in coastal areas. Fisheries contribute about 1 per cent of India's GDP, which forms about 4.12 per cent of the agricultural GDP (2003-04). The total fish production during the four decades (1950-51 to 1990-91) showed an annual average compound growth rate that varied between 3.35 to 4.62 percent. About 12.2 lakh fisherfolk operate diverse types of craft-gear combinations with regional and seasonal variations all along the Indian coastline. The secondary sector provides employment to more than 15 lakh people and another one lakh people is employed in the tertiary sector. Decline in catch rates coupled with increasing domestic and international demand of high value species has resulted into more conflicts in sharing of resources, increase in migration of fishing units and labourers, emergence of multiday fishing even extending beyond 15 days and consequent socioeconomic disturbances. In this context, there is good scope to increase our food fish production through open sea mariculture by adopting location specific appropriate technologies.

The backdrop of fisheries legislations enacted in India traces back to 1857, when the Indian Fisheries Act was endorsed. It was meant to regulate riverine fisheries and fisheries in inshore waters, to prohibit the use of poisons and dynamite in fishing, and to protect fish resources in selected waters through regulation of, among other things, the erection and use of fixed engines (the reference is to nets, cages, traps, *etc.*), the construction of weirs, the use of nets of certain types and dimensions, *etc.*

The present day scenario is governed by various sets of enactments essentially having bearing on the marine fisheries sector. These legislations include Maritime Zones Act (1976) which recognizes the sovereign rights to conservation and management of living resources in the Indian EEZ, in addition to their exploration and exploitation. Another important regulation governing the marine fisheries is Maritime Zones of India (Regulation of Fishing by Foreign Vessels) Act (1981) and Rules (1982). Fisheries within the 12-mile territorial limits are managed under the Marine Fishing Regulation Acts (MFRAS) of the maritime States of India. The main emphasis of MFRAS is on regulating fishing vessels in the 12-nautical mile territorial sea, mainly to protect the interests of fishermen on board traditional fishing vessels. Thus, the Act has been mainly used for the purpose of maintaining law and order at sea. The MFRAS were first implemented in the States of Kerala and Goa in 1980. They were subsequently enacted in other States, the latest being in 2003, in Gujarat. While the earliest MFRAS were enacted only for regulation of fishing vessels along the coastline of the State, the Gujarat MFRA provides for protection, conservation and development of fisheries in inland and territorial waters of the State of Gujarat and for regulation of fishing in the inland and territorial waters along the coastline of the State. The Coastal Regulation Zone Protection Act, (1986) outlines a zoning scheme to regulate development in a defined coastal strip. The Notification defines the coastal stretches of seas, bays, estuaries, creeks, rivers and backwaters which are influenced by tidal action in the landward side, up to 500 m from the high-tide line (HTL) and the land between the low-tide line (LTL) and the HTL, as the CRZ. The Environment Protection Act, (2002) authorizes the Central government to protect and improve environmental quality, control and reduce pollution from all sources, and prohibit or restrict the setting and/or operation of any industrial facility on environmental grounds. The Biological Diversity Act (2002) provides for the conservation of biological diversity, the sustainable use of its components and, significantly, the fair and equitable sharing of the benefits arising out of the use of biological resources, knowledge and related matters. Open sea mariculture requires adequate legislative support from the Government for leasing out of suitable sites. The legislation so far enacted by the central Government and various state Governments focussed mainly to regulate the harvesting of open sea resources rather than considering the farming in the sea.

At present (2003-04) there are 2251 traditional landing centres, 33 minor and 6 major fishing harbours in the marine fisheries sector of India. About 1.77 lakh of fishing crafts are in operation comprising 76596 traditional non-mechanised fishing crafts, 50922 motorized crafts and 49070 mechanized crafts operating different gears as shown in Table 1.

Table 1 Growth rate of marine fishing fleets in India (1961-62 to 2003-04)

Year	SECTOR							
	Non-mechanised		Motorised		Mechanised		Total	
	Number	Growth Rate (%)	Number	Growth Rate (%)	Number	Growth Rate (%)	Number	Growth Rate (%)
1961-62	90424	—	—	—	—	—	90424	—
1973-77	106480	18	—	—	8086	—	—	—
1980-81	137000	29	—	—	19013	135	156013	73
1997-98	160000	17	32000	—	47000	147	239000	53
2003-04	76596	-52	50922	59	49070	4	176588	-26

The trends in the growth rate of fishing units indicate the possible phasing out of non-mechanised Canoes at least in certain regions, which ultimately reflected a negative growth of 52 per cent by them during 1997-98 to 2003-04. This downtrend is compensated in the motorised sector implying large-scale motorisation of existing traditional crafts. Mechanised crafts displayed a major boom during 1980s and 1990s. The growth rates were 135 and 147 per cents respectively in 1980 and 1997, due to diversification and extended area of operation. While mechanized trawlers and gillnetters are common all over Indian coast, dolnetters are popular in Gujarat and Maharashtra coasts, purseseines in Goa, and Karnataka coasts, pair trawling in Tamil Nadu and sona boats in Orissa coasts, depending on the regional and seasonal abundance of resources. When the technical efficiency of a particular gear is better than the other, the lesser efficient gears gradually disappear from the operation.

The gross capital investment on fishing units in Indian marine fisheries sector during 2003-04 works out at Rs. 10,532crore in which mechanised sector constitutes about Rs. 9,049 crore, more than a three-fold increase from 1997-98. The increase in investment on mechanised trawlers and gill-netters are comparatively higher than other sectors. The capital investment on motorised sector also almost doubled from Rs.456 crore during 1996-97 to Rs. 861 crore during 2003-04. However, as expected, the non-motorised sector has shown a decline in investment from Rs. 923 crore during 1996-97 to Rs. 622 crore during 2003-04 in tune with their decline in production and diminishing returns. Further, substantial numbers of these units were converted into motorised units.

The estimated gross capital investment on fishing equipments alone works out to Rs. 4,117 crore at 1997 price level , in which 58 per cent is in the small scale mechanized sector, 9 per cent in deep-sea vessels, 11 per cent in motorized sector and 22 per cent in non-mechanized sector. It may be noted that out of the total capital investments on fishing equipments, during 2003, 86 per cent is constituted by mechanised sector, 8 and 6 per cents respectively by motorised and non-mechanised sectors.

The overall per capita investments of an active fisherman in 2003-04 was Rs.86,290 ranging from Rs.17,024 in the non-mechanised sector to Rs. 2,19,319 in the mechanised sector. During 1997, the overall per capita investment was Rs. 40, 363, where the investment per head in mechanised sector was Rs.1, 25,689, motorised and non-mechanised sectors invested Rs. 26, 835 and Rs. 13,979 respectively per active fisherman in India. Further, fishing intensity is directly related with capital investment vis-à-vis number and type of nets they are possessing. A catamaran owner having different types of nets can have more number of fishing days. If he is having only one type of net, he will be having only lesser number of fishing days. In India, most of the non-mechanised fishermen are having one or two fishing nets, which are not sufficient for efficient operation for the whole year.

In the open access marine fisheries, mode of ownership on means of production by fisherfolk greatly influences the occupational pattern and socio-economic status. The type and number of fishing implements owned is the yardstick to measure the economic well being of a fisher household. In India, hardly 13 per cent of the active fishermen in the marine fisheries sector have ownership on craft and gear in 2003 and another 3 per cent possess only gears. The proportion of owner operators in marine fisheries declined over the years with the increasing capital requirement for possessing motorized and mechanized fishing units. In the mechanised sector 12 per cent, motorised sector 9 per cent and traditional sector 21 per cent have ownership on crafts and gears. Most of the non-motorised units are operating as family enterprises not even realizing the operating cost of the labourers. Lack of finance and credit facilities does not allow these fishermen to go for modernization and come out of the vicious circle of poverty and low-income trap. Disguised unemployment is rampant in capture fisheries and fisherman need alternative avocations for their livelihood. The inter and intra sectoral migration also need to be arrested for balanced and sustainable development of the coastal sector. Fishermen are in general unwilling to shift from fisheries sector for any other employment. Hence, mariculture is one of the most acceptable and viable occupations for coastal fisher folk.

A report of the consultative group on international agricultural research states that within the next 15 years, fish farming and sea ranching could provide nearly 40 per cent of all fish for the human diet and more than half of the value of the global fish catches. According to a report of the FAO, the world aquaculture production is projected to increase by 2.69 times by 2025 AD. India as a leading country in Asia in aquaculture production should be able to achieve at least a production of 2mt (0.1mt finfish, 1.0mt crustaceans, 0.3mt molluscs and 0.6mt seaweeds) through mariculture by the year 2025 AD, *i.e.*, 3.9 per cent of projected global aquaculture production of 51.8mt. With improvements in the domestic market, diversification of marine products exports, availability of a vast range of cultivable candidate species, several culture technologies and hydro climatic (or agro climatic) zones for coastal mariculture and sea-farming, India is poised to become one of the world's leading producers of mariculture products.

Issues related to Coastal Regulation Zone (CRZ), Integrated Coastal Zone Management (ICZM) and the unfounded apprehensions that coastal mariculture would adversely affect the environment, are leading to unnecessary or avoidable litigations retarding the growth of the mariculture sector. It is worth to note that the present shrimp oriented, land-based coastal mariculture has resulted in the under-utilisation of the technologies developed for the culture of bivalves, seaweeds and pearls, and hence, requires being diversified and broad-based to take maximum advantage from the high production potential of tropical aquaculture farms.

The information from various segments reveals that the marine fisheries in India is currently undergoing through a phase of socio-economic cum ecological turbulence. A versatile study on responsible fisheries observes that the major factor that endangers its sustainable utilization is the open access nature of marine resources and the veritable lack of an enforceable property rights regime or unanimously agreeable regulatory mechanisms. There are many activities, which adversely affects the sustainability of marine resources including shallow water mining, use of improper crafts, ghost fishing, destruction of mangrove forests, *etc.* Development processes such as urbanisation, industrial pollution and eutrophication of estuaries have also jeopardised the fragile ecological dynamics of the coastal area.

The concept of Responsible Fisheries advocated by FAO through its Code of Conduct for Responsible Fisheries is an epitome among global efforts for realising the coveted goal of sustainable utilization of our marine resources. The Code is a landmark in marine development thinking as it represents the consensus achieved by more than 150 nations across the world on the directions we should follow in order to avoid resource depletion due to irrational utilisation behaviour pattern shown by various stakeholders. Stock enhancement through artificial reefs and fish farming in the cages are better technological options to counter problems of resource depletion.

Scope for open sea mariculture

Prospects of Open sea mariculture

- Alternative source of income
- Better resource productivity
- Entrepreneurship development
- Societal empowerment lower and
- Lower gestation period.

Problems of cage culture

- Lack of coherence among social groups
- Issue of free rides among the commons
- Problem of mute participation
- lack of social commitment
- Problems in revenue sharing system
- Resource ownership issues
- Need for finding progressive fisher folk
- Risk taker and innovator
- Entrepreneurship development

The following interventions are required for promotion of cage culture

1) Cages
   - Increasing the life of the cage
   - Cost reduction of the cage
   - Optimization of cage and mooring system
   - Provision of subsidies for the cage construction

2) Site selection and candidate species
   - Identification of congenial site considering the hydrographic and environmental parameters
   - Identifying location specific candidate species with better productivity inputs are required

3) Inputs
   - Input standardization
   - Cost minimization
   - Revenue sharing approach

The other interventions are increasing density and revenue sharing approach.

Participatory approaches for cage culture

- Sharing of accountability and responsibility
- Security for group conflicts and sabotage
- Institutional support in the event of uncertainties
- Reward for risk bearing
- Encouraging a public private community participatory approach

There is enormous scope to enhance food fish production from the sea through mariculture. Adaptability of capital intensive fishing technologies in the capture fisheries will further escalate the cost of production and price of fish. Unlike land, water resource is not a limited factor of production for coastal states for adopting mariculture practices. Hence, legislative support is vital for the promotion and propagation of open sea mariculture. It provides better option for enhancing the livelihood opportunities of the fisherfolk in the coastal sector without any migration.

Geographic information systems and site selection issues of open sea cage culture

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The GIS paradigm

As is much known in the Information Technology circles, a pair of numbers narrates the past, describe the present and in fact most importantly seal the future. The pair obviously means the latitude and longitude of the location any where under the sky. This perspective of referencing any type of information be it scientific, sociological, psephological or economic, has taken the world of analytics by storm in past quarter of a century. The last decades of the previous millennium were dotted with spurt in methodologies and software which were totally dependent on this type of geo-referenced data. Information collected serially over time, popularly known as time series, always had a huge role to play in studying the impact of changing eras and centuries at larger level and seasons and cycles in shorter duration. The surreptitious shadow cast by the effect woven by time on the trait of interest had always caught the imagination of analytical computational experts, especially econometricians. Similar to the perpetual latent impact of temporal causes, the geographic factors also have been exhibiting impact on many an important scientific phenomenon. Most of the natural resources available on earth are bound to be impacted by their geographic position on the earth's crust. This is best explained by the availability of resources like ores and mines in certain pockets on earth. Though geological reasons arising from the core of earth are reasons for their pattern, the external environment like the atmospheric parameters and other natural habitation like forests etc have a very important role in moderating their availability. Hence the idea of viewing the geographic location as another latent cause of expression of any important parameter alongside temporal references started clawing up on the ladders of analysts and a whole new vista of analytical reasoning emerged. That vista loosely named as analysis of geo-referenced series or spatial analytics has a very important requirement, a series of spatially referenced data spread across temporal spectrum. The series of spatio- temporally arranged data points are popularly referred to as Geographic Information System or GIS in short. When originated the GIS concept was mostly applied to terrestrial references. The absoluteness with which the terrestrial data points could be uniquely referred by a pair of geographic coordinates amply suited the development of databases which were strongly rooted on those coordinates. Hence a plethora of application-ware were developed which led to the possibility of developing maps on the digitised geographic platform showing various intensities with which the parameters of interest were available. These maps are popularly referred to as "Thematic Maps" and they formed an essential part of many a dossier on resource spread, intensity and availability. But GIS is much more than development of thematic maps. The range of applications is multifaceted including geo statistics, modelling and development of decision support systems.

Although terrestrial GIS has been quite in vogue in the past quarter century or so, the last decade saw the emergence of another dimension to it, literally. The Marine Geographic Information System (MGIS) has the added dimension of depth alongside the latitude and longitude. It has been a much discussed and researched topic that the marine fauna and flora demonstrate huge diversification down the bathymetric locales. Marine GIS must first adapt to the characteristics of the marine world and marine data and the dynamic relations among the various components of the marine environment. Thus MGIS opens up a new world of opportunity as well as challenge which is 3 dimensional to say the least.

At this juncture the importance and utility value of 3D marine data sets as compared to the lat- long based terrestrial datasets have to be clearly understood. The depth component, needless to add, holds the key towards unravelling a huge treasure of wealth and its dynamics across the geographic vastness as well as their vertical upheaval. Such a three coordinate time series can always aid in shoring up the onerous task of studying the underlying interrelationships, trend, seasonality etc., which classically suit spatio-temporal analyses. Such a system can mutually embellish species life history data which in turn can aid in lucid portrayal of the progression down the prey- predator web. The interlinked nature of coastal, oceanic and fisheries information is for everybody to understand and study. The invaluable contribution that such a marine GIS can make while attending to the conflict between marine object dynamics and management policies is anybody's guess. Another topic worthy of discussion is the type of input getting into a marine GIS including those obtained by meteorological gadgets as well as by Global Position Systems. A variety of technical disciplines and issues are associated with the nucleus of marine GIS technology. It is quite constructive to have stress on the importance of meta data while detailing the basic types of data on the very first occasion.

The goal of marine GIS has always to be kept in mind before trying to understanding the technical intricacies. Ranging from exploratory input to full fledged predictive paradigms, the MGIS has a huge chunk of goals which could be attained using specially drafted software. The core concepts of MGIS starting from location up to diffusion have strong relationship with various types of information collected at various stages of the resource regeneration system. One standout example that could be cited is the association of regions using chlorophyll contents and sea surface temperature. Another way of looking at this whole paradigm is to pose self quizzing queries and seeking answers like, "Where was it"; "How long was it existing?"; "Is there any other resource abundant nearby?" etc. A model which satisfactorily answers the above asked questions would be the one which would be the best.

MGIS and Oceanography

GIS in general and MGIS in particular are affronted by Oceanographic concepts in many ways. The extent of influence can be well understood by the simultaneous consideration of micro scale turbulence to enormous gyres, both of whom have a serious role to play in shaping up the Information System. The role of Remote Sensing in these oceanographic data consideration has also been a topic of discussion and debate. Needless to say a management interface for coastal and oceanic environment is a much needed reality for any nation caring for justifiable exploitation of its resources. No better argument is needed for this aspect of exposition than the fact that 90% of pollutants generated by economic activities end up in coastal zone. It is a matter to ponder that the historic reasoning behind oceanic upheavals and their vulnerability to climate change which is a present day priority, have been comprehensively juxtaposed. The inevitability of viewing the coastal zone from the stakeholder's point of view in the holistic perspective rather than a fractured sector by sector basis can never be under stated.

Innumerable citations and references are available for the linking of oceanographic parameters with a MGIS Starting with datasets vis-à-vis their relevance to marine geology to information based accrued over hydrological sounding and multi-beam sonar systems, the review could be elaborate and informative Please refer V. Valavanis (2002) for an excellent review.

The role of GIS in flood assessment is another important facet full of references on digital elevation models, geographic flood information system and the world map of natural hazards. The citations available in Valavanis (2002) sufficiently sum up the efficacy and range of the tool.

An exposition on the application of GIS in coastal and oceanic management throws up interesting works like Natural Resources Management Facility for Mozambique, which primarily aim at social development like employment generation and poverty alleviation through participatory and sustainable management of natural resources. Certain attempts to rank coastal regions on their environmental sensitivity and pollution hazard with the help of GIS have also been discussed in literature.

Throwing spotlight on yet another facet of GIS, work done by researchers across the globe by integrating hydrodynamics and morphometry are worth revisiting (Valavanis (2002)). The analytics done in describing a dynamic coastal zone like a lagoon ecosystems along with identification of main aspects of their degradation and identification of critical environmental parameters as also recovery plan will really spur the researcher towards seeking more on this application of GIS.

There are multitudes of references on GIS application for study of oil spills in oceans, sea level rise and natural and artificial reefs which are bound to add strength and objectivity to the more publicized perception on GIS. Popular techniques like ecological modelling, scenario building and vulnerability index computation on a geo referenced platform have also been some of the much highlighted applications of MGIS. The MGIS is also a widely used tool to study and manage lesser focussed marine contingents like submerged aquatic vegetation, wetlands and watersheds.

Literature is replete with initiatives taken by various governmental and research establishments towards Oceanographic GIS. The developments in the Gulf, US and Europe have been worth chronicling (Valavanis (2002)). But the flagging of GIS as a solution to the ever increasing data volume and complexity should be approached with caution, as prima facie the statement indicates data redundancy and Information Systems target something primarily different. The issue of handling voluminous datasets usually target solutions in the mould of data warehousing and Information Systems should not be equated with them.

In all there are around 20 unique efforts carried out at various locations across the globe till the turn of the last millennium Valavanis (2002). Most of the information systems mentioned are of very high environmental importance and their role in arriving t multidisciplinary answers to important scientific and societal queries can never be understated.

Any logical extension of global examples of MGIS would be the focus on data sampling methods which broadly outlines the gadgetry involved in the collection of physical, chemical and biological data that add up to make the system. The point that commercial establishments have fanned out their research and analytical wings across the globe to sustain their interests through Oceanographic trend monitoring, is probably one single stand out fact. It effectively sums of the impetus being thrust on this branch of study and the enormity of changes and paradigm shifts which are just round the corner. The information on various satellite sensors and the corresponding internet sources are real highs which have augmented the reach and purpose of MGIS. The development of other sources of remote sensed data like sensing platforms, Ocean Data Acquisition System etc. is a meticulous collation on advances in Oceanographic data sampling. Plethoras of urls in the internet have comprehensive information regarding the details of the gadgets.

Another interesting issue discussed during the course of this topic is the one pertaining to real-time organisation of marine survey data. Though it may sound similar to the type of data integrations discussed so far to an innocuous reader, this throws up more light into the integrated analytics that follow the online data accumulation. Hardware innovations like tape robot is undoubtedly a fascinating interlude to this, but it has the capability to derail a serious analytical researcher by leading him into the fascinating world of clustered data storage management.

This discussion could be rounded of with a detailed exposition on the methods and techniques adopted in identification and quantification of gyres, classification of surface waters, identification of temperature and chlorophyll fronts and tracking and measurement of upwelling. The mode of discussion is a judicious admixture of generic introduction followed by specific examples of the techniques application across the globe. The description of the unified efforts involved in the mapping of sea beds where local and remote methods of data derivation come to the fore cited in Valavanis (2002), could aptly wrap up the extensive discussion on GIS and its application in Oceanography.

MGIS and Fisheries

MGIS with a firm footing on various sources of information is obviously well poised to have many applications in the fisheries sector which have direct impact on the fisher folk. Unlike hydrology and other physicochemical parameters, fish capture and availability based indicators have a very huge say on the holistic management of fisheries encompassing social, economic, technical, ecological and ethical aspects. Any information system that has roots on this type of core information will have a whole lot of relevance and priority amidst its class of systems. Naturally more criticisms and evaluations are bound to tow them. The Net is replete with references wherein umpteen instances of applications based on MGIS coming to the aid of fisherfolk and planners in various countries. Interestingly another interesting aspect of the link between Information Systems and Fisheries is the role of geostatistics (spatial statistics) which is an established branch of statistics inquiry into the geo referenced datasets. Albeit tools like kriging and variograms have been in vogue in the GIS universe they are basically statistical tools which are adopted or adapted to suit to the requirements of geo referenced datasets.

A large number of techno-administrative information consortia formed across the world catering to the fisheries GIS (Valavanis (2002)). The chronological developments that have taken place in the electronic documentation and documentation of strides made by this branch of IT are worth browsing through. The first GIS conference at Seattle in 1999 is a proof for this. While reiterating the intricacies involved in the comprehensive understanding of the relationship of fish and its environment, the conference stressed that it is time to have a syndicated effort to publish scholastic efforts in this direction. The statement – “The time has arrived for a Fisheries GIS journal…” made by the participants (although it was made in early 2000’s) sums up the sincerity with which this document is prepared. Although the trickles which were chronicled in many publications have turned into a stream nowadays, an exclusive periodic publication of articles on GIS for marine fisheries is still elusive.

The four stages at which GIS on fisheries can be utilised are worth underscoring. Most of the planning and policy compilers get saturated with the thematic maps and conceptual 3D output generated by GIS software. The other stages viz. which area meets the set requirements, presence or absence of a pattern over space and scenarios which can arise as a result of decisions and regulations are weightier in purpose but less in vogue when it comes to utilisation. Hence it is mandatory for any discussion on adoption of GIS to equally stress all the four levels of the tool's application. One important aspect to be highlighted on marine fisheries management through GIS is a citation of Senegalese case (Valavanis (2002)) which can be quite useful in the context of any similar footed nation. GIS was utilised to identify areas of conflict between artisanal and industrial fisheries and further proceeding on to the explanations for fisheries management on the degree of respect for the limits of regulated fishing areas and spatial fishing strategies as per the major seasons. The development of bioenergetic physiological principles augmented generalised spatial dynamic age structured multistock production model is a refreshingly new vista of GIS application in fisheries research. As another application of GIS in marine fisheries management, the mapping of biomes, large marine ecosystems etc. which go a long way in evaluating and explaining the distribution of marine features (e.g. primary production), which are not usually focussed upon under conventional studies can be mentioned. In a way there is an exhaustive collection of references which unravels all the possible utility areas of GIS in marine fisheries management (Valavanis (2002)).

The role of GIS in aquaculture needs no further emphasis as it is almost similar to the terrestrial GIS wherein primary role is in site selection. Herein come the issues of planning, designing and execution of aquaculture assignments, apart from simulation backed economic forecasting tools, which is a real plus for observers with less exposure.

During the turn of last century some working models to manage and study thriving inland fisheries like freshwater salmon fisheries were developed (Valavanis (2002)). The discussion includes inclusion of environmental variables alongside the classical parameters like expanse of water bodies etc. which gives a ringside view of initiatives made in the first part of this decade.

The use of remote sensing tools in the applied portion of data collation is another aspect of study. The grid construction and partial ground truthing of the remote recordings are all inseparable parts of this methodology and they can always be adequately described with the help of certain specific studies whose outputs like maps etc. have been provided (Valavanis (2002)). A list of more than 60 Internet sources of GIS databases embellishes the chapter and it has been one of the unique plus points of this book as such. A couple of snapshots from some GIS databases which include very pertinent theme maps like gear pressure on cephalopod populations in SE Mediterranean and catch areas of Octopus in the same area are excellent techniques to communicate with the starter Valavanis (2002). Developments like mapping of spawning grounds, essential habitats, migration corridors etc. which give a taste of how powerful and useful GIS can be in a fishery planner's hand.

MGIS and cage culture

Open sea cage culture being an operation wrought with a lot uncertainties ranging from physical parameters of the ocean to the biotic and chemical factors affecting the morbidity and mortality rates of the animals to be cultured has to be necessarily based on informed plan. An informed plan is one where studied decisions are taken before the blue print is prepared which in turn are based on various parameters of concerned recorded pertaining to the area of operation. Hence when the ocean can pose challenges at least on three dimensions with a whole lot of physical and chemical parameters on the tow. It is here the role of a geo- spatial aggregation of parameters comes to prominence.

Site selection for cage culturing exercises will involve specific inputs on the following parameters:

(i) Bathymetry

(ii) Currents

(iii) Shelter and

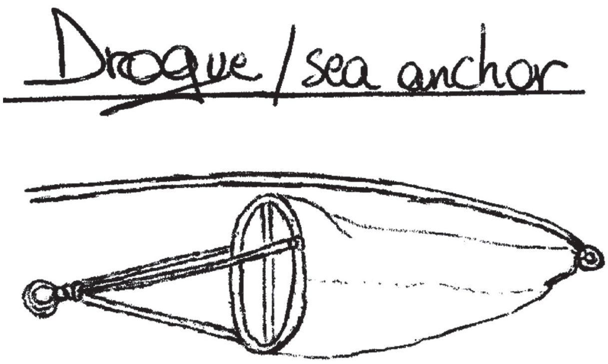
(iv) Water Quality Variations

To explain this with an example to have a cage culture study based on Salmonids, it is essential to gather information on depth (m), current (m s-1), dissolved oxygen (mg l-1), salinity (%) and temperature (æ%C). From established literature inputs on the possible range and optimum values of these parameters might have to be collected. Such data coupled with topography of the site and exposure of the same would be used in the site assessment.

Towards achieving this preliminary studies conducted in the area focussed have to be collated and compiled. Then suitable software to store/ update and analyse the data may have to be selected. This software could range from free to very cheap shareware to software meant for educational/ research institutions to full fledged commercial software like Arc GIS etc. As the next step the topography of the broader location where cage is planned to be set up along with the nearby coast details like bay etc should have to be mapped. The outline map of the greater area like bay could well be a definitive starting point. Suitably scaled maps have to be drawn outlining the broader area of focus.

The second task is to generate a bathymetric contour map of the broader area of interest which could be achieved by making a series of boat transects at constant velocity and bearing using echo-sounders. Depths such recorded could be plotted onto the base map.

The third task of measuring the velocity of currents is done by using hydrographic drogues (sea anchors) (displayed below).



The drogues could be located at timed intervals from boats using sighing compasses.

The fourth parameter of exposure could be categorised by estimating wave heights at different locations. Expected wave heights depend upon water depth and wind velocity, duration of fetch over which wind passes before impacting the proposed location.

The wind data could be obtained from nearby weather stations.

The physico-chemical properties of the water like dissolved oxygen, temperature and salinity could be recorded at a number of fixed locations at different stages of tidal cycle using instruments like Oxygen meter and inductive bridge salinometer.

The whole database in GIS pertaining to the area under focus should preferably be prepared in two scales which are significantly different in resolution, something like 25 x 25 metre block or 10 x 10 m block based.

In any typical GIS software the different types of information like outline map, points of observation, bathymetric data, current and exposure data are entered in the form of different layers called grids. Usually the base grid containing the blocks is kept transparent and the other observed data sets are over laid on them either as points or shapes or themes.

Apart from these specific information that needs to be known for the type and size of cages, general information of the broader area like pollution, availability of power (electricity) and presence or absence of tourist-related or ecological limitations.

In the following series of pictures provided in the paper by Ross et al (1993) graphically explains the details of one such GIS mapping done to locate suitable ambience for Salmoid cages.

For proceeding further the following are the parameters estimated during the exercise.

(i) Mean depth : 6.8 m

(ii) Current velocity : Upto 138 cm s-1

(iii) Speeds falling in acceptable range : 80%

(iv) Nature of velocities: High at periphery; low near centre

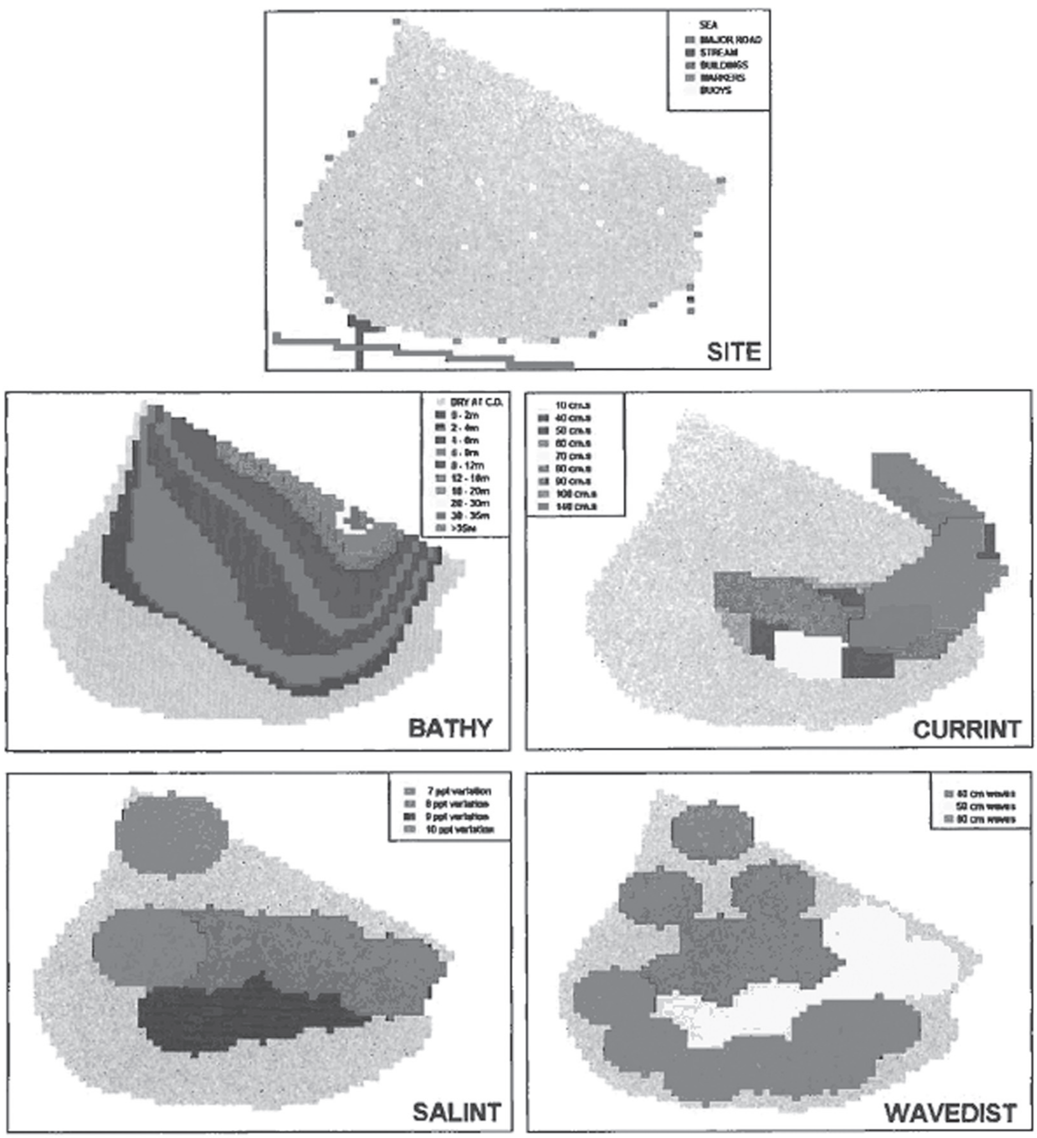
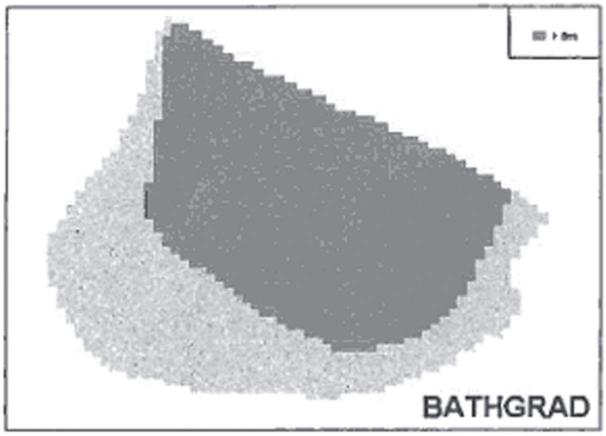
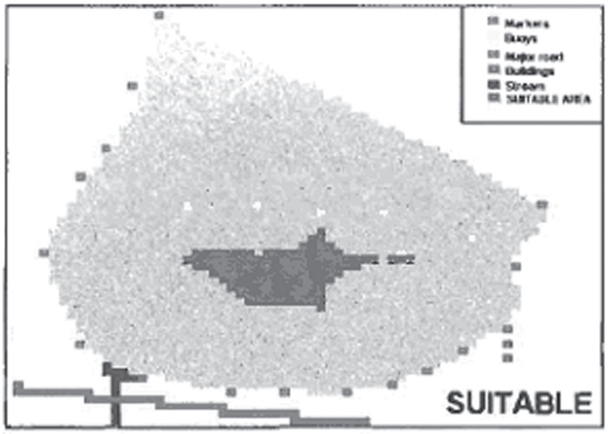
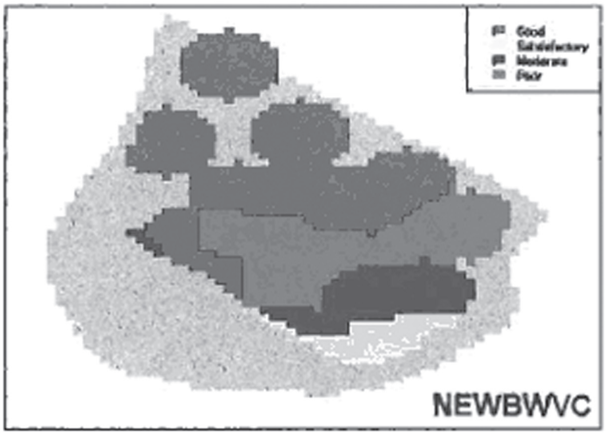


Fig. 2. The base map, SITE, digitised in OSU MAP.
Fig. 3. The bathymetric map of Camas Bruaich Ruaidhe, BATHY.
Fig. 4. Interpolated current distribution in Camas Bruaich Ruaidhe, CURRINT.
Fig. 5. Interpolated salinity distribution in Camas Bruaich Ruaidhe, SALINT.
Fig. 6. Interpolated wave height distribution in Camas Bruaich Ruaidhe, WAVEDIST.







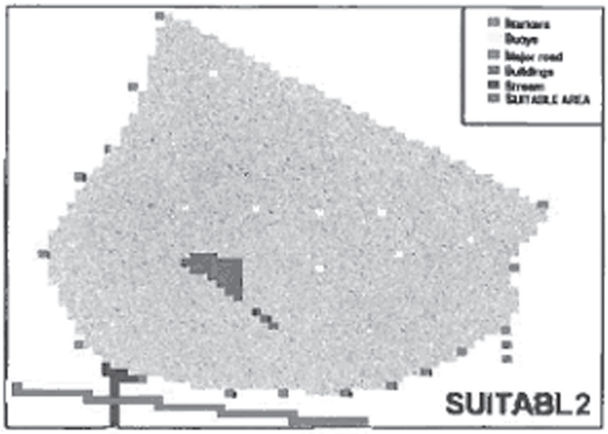


Fig. 7. Area suitable for cage installation based on bathymetry, BATHGRAD.
Fig. 8. Area suitable for cages based on bathymetry and wave heights, SAFEWAVE.
Fig. 9. Area suitable for cages based on bathymetry, wave heights and currents, BAWVCURR.
Fig. 10. Optimum area selected for cage installation, using the criteria given in the text, SUITABLE.
Fig. 11. Area suitable for cages based on bathymetry, wave heights and currents, recalculated using different selection criteria, NEWBWVC.
Fig. 12. Optimum area selected for cage installation, using the selection criteria applied in Fig. 11, SUITABL2.

(v) Spatial interpolation: CURRINT

(vi) Dissolved Oxygen levels: 8.6 to 11.0 ppm (at high tide) ; 8.2 to 10.4 ppm (at low tide) (no difference between surface and bottom readings)

(vii) Water temperature: 12.8C to 13,4 C and 12.9C to 13.0 C at high and low tide respectively. (well within the tolerance level)

(viii) Salinity parameter: 19% to 29%

(ix) Wind speeds: 61 km h-1 and 85 km h-1

(x) Fetches observed 4.44 (NW), 3.42(NE) and 2.37 (NE) were the longest

(xi) Wave heights: 0.4 to 0.8 m

Based on the type of data collected over a reasonable period of time scorecard was prepared for the site selection. The scores with not more than two to three outputs were decided based on the various parameters discussed above and the highest score is given to the blocks which have the most favourable parametric value.

Finally to decide on the suitable block (25 x 25 m) or (10 x 10m) the interpolated wave heights coupled with bathymetry will decide the score on the depth aspect. Similar recoding based on the scores for other parameters like water quality was conducted and the most ideal pocket was selected based on the pocket/ block which scored the maximum. (SUITABLE in the picture shown above).

While this method seems to be straight forward and deeply rooted in the classical analytical traditions, the over dependence of the precision of parameters estimated makes it overtly vulnerable to instrument/ equipment errors. But one huge plus for this approach is the avoiding of individual bias and subjectivity while zeroing in on the location of choice. Still unfavourable locations can be removed at the outset by way of observing cage depth and limiting beyond 1.5 times of the depth. Such dictums like avoiding velocities less than 5 cm s-1 and those above 50 cm s-1 should be built keeping in mind the species to be cultivated. The sequences to be followed in the decision making process should be ceremoniously followed for any interchange of layers may produce different output.

With the advent of brutal computational power the process of decision making especially the computations involved are of no big threat. But an assiduous selection of decisive parameters and careful measurement of parameters during survey is a must for any successful use of MGIS technique for selecting Cage locations for mariculture.

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Economic analysis of cage culture of sea bass

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Introduction

Open sea cage farming can be referred to as the method of culturing aquatic organisms in enclosed cages made of various materials in the seas. The true cage farming is of recent origin and a well established practice in Southeast Asian countries. The practice developed independently in a number of countries, all in Southeast Asia. Presently, cage culture is developing fast and turning to a highly commercialized business activity in many Asian countries.

In India, pen culture and pond culture experiments were done along the southeast coast using the seed of rabbit fish, groupers and sand whiting. Similar trials were also done along Kerala and Karnataka coasts. In the recent years, open sea farming was done at Visakhapatanam and cage/pen culture experiments were conducted at Calicut and Vizhinjam Research Centre of CMFRI (CMFRI Annual Report, 2006, 07).

During 2008, fourteen cages were launched across the east and west coasts. The failure witnessed in the launch of the first cage during May 2007, formed the stepping stone of success later in the same place. The lacunae in the launching of the first cage were rectified and successfully re-launched during December 2007, which gave a substantial harvest of sea bass in April 2008.

Economic analysis

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

The economic performance of the cage culture experiment is worked out by calculating the annual fixed costs, variable costs and the annual total costs from the cost side. From the returns point of view, the harvest from the cage, the gross revenue from the sales of the harvest is worked out. Using the cost and returns figures, the following economic indicators are estimated to test the economic viability and financial feasibility of any enterprise.

Table 1 Indicators of economic performance of the cage culture enterprise

Sl.No.	Economic Indicators
1	Initial investment of the cage
2	Fixed cost (For crop duration of six months)a) Depreciation b) Insurance (2% on investment)c) Interest on Fixed capital (12%)d) Administrative expenses
3	Total Annual Fixed cost (A)
4	Operating costsa) Cost of seedlingsb) Cost of feeding and other labour chargesc) Interest on working capital (6%)

5	Total Operating or Variable cost (B)
6	Total cost of production [Row(3)+Row(5)]
7	Yield of sea bass (in kg)
8	Gross revenue [(7) * Price per kg]
9	Net income [(8)-(7)]
10	Net operating income [(8)-(5)]
11	Cost of production (Rs./kg)[(6)/(7)]
12	Price realized (Rs./kg) (8)/(7)
13	Capital Productivity (Operating ratio) (5)/(8)

The different economic indicators of the economic performance of cage culture enterprise are worked to assess their performance in Table 1. This will serve as the guidelines to the institutional agencies who are extending the financial support to the enterprise.

Case studies

The detailed economic analysis of the **experimental cage culture practice** demonstrated in Visakhapatnam (Andhra Pradesh) and Balasore is given below to indicate how the economic analysis of the enterprise is done.

(A) Visakhapatnam

Table 2 Initial investment of the cage culture farm of 1061 m^3

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

Table 3 Details of Annual Fixed cost

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

Table 4 Details of Annual Variable cost of cage culture (for a crop duration of seven months)

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

Table 5 Economic indicators of the cage culture of *Lates calcarifer*

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

(B*) Balasore*

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

Table 6 Economic analysis of the experimental cage culture demonstration at Balasore

Sl. No.	Details of cost and returns	Amount (in Rs.)
1	Initial investment for a 6m diameter cage	3,00,000
2	Fixed cost (For crop duration of six months)a)Depreciation b)Insurance (2% on investment)c) Interest on Fixed capital (12%)d) Administrative expenses	30,0003,00018,0003,000
3	Total Fixed cost (A)	54,000
4	Operating costsa) Cost of seedlingsb) Cost of feeding and other labour chargesc) Interest on working capital (6%)	50,0001, 75,0006, 750
5	Total Operating cost (B)	2,31,750
6	**Total cost of production (Six months)**	**2,85,750**
7	Yield of sea bass (in kg)	3,032
8	**Gross revenue from 3032 kg**	**5,75,760**
9	**Net income (8)-(5)**	**2,90,010**
10	**Net operating income (Income over operating cost)**	**3,44,010**
11	**Cost of production (Rs./kg) (6)/(7)**	**94.24**
12	**Price realized (Rs./kg) (8)/(7)**	**189.89**
13	**Capital Productivity (Operating ratio) (5)/(8)**	**0.50**

The culture of sea bass yielded 3.03 tonnes of sea bass during the harvest conducted at the end of six months, thus earning a gross revenue of Rs. 5,75,760 to the participants. The culture of sea bass earned a net operating income of Rs. 3,44,010 at the end of six months and a net profit of Rs.2,90,010 at the end of the same period. The cost of production per kg of sea bass worked out to Rs.94.24 against the value realization of Rs.189.89per kg. The capital productivity measured through operating ratio worked out to 0.80. These economic parameters indicate that this open sea cage farming of sea bass is economically viable.

Conclusion

Thus it is seen from the above results that the economic analysis of the experimental cage culture farm has worked out successfully with higher net operating income and net income in a crop period of seven to nine months. It is to be noted that once the practice is further expanded to many areas and farms, the cost will decline due to the economies of scale of operation. Thus it could be concluded that the open sea cage farming is a viable alternative and economically & financially feasible mariculture operation for the stake holders to make use of. The State Fisheries Departments and the Development Organizations like NFDB can promote the concept of cage culture on a large scale with their institutional and financial support availing the technical expertise developed at CMFRI.

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