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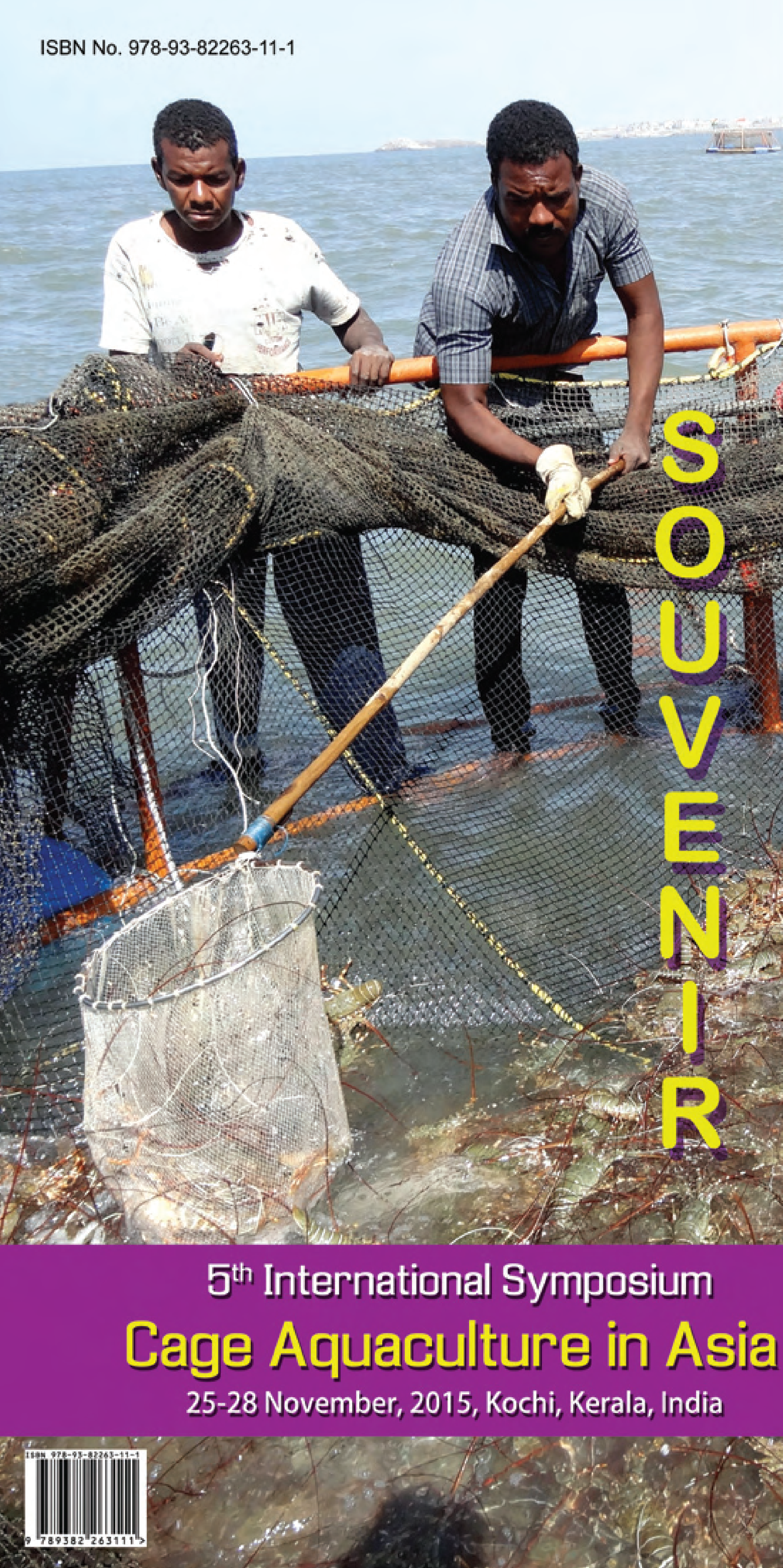

CAGE AQUACULTURE IN ASIA

November 25-28, 2015 Kochi India

CAA5

सत्यमेव जयते

भाकृअनुप
ICAR

सी एम एफ आर आइ
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FOUNDED 1984

ASIAN FISHERIES SOCIETY
FOUNDED 1984
INDIAN BRANCH

5th International Symposium

Cage Aquaculture in Asia

25-28 November, 2015, Kochi, Kerala, India

ISBN 978-93-82263-11-1


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Souvenir

5th International Symposium on
Cage Aquaculture in Asia
CAA5

November 25-28, 2015
Hotel Radisson Blu, Kochi, India

Asian Fisheries Society
ICAR-Central Marine Fisheries Research Institute
Asian Fisheries Society Indian Branch

Souvenir

5th International Symposium on

Cage Aquaculture in Asia

CAA5

ISBN No. 978-93-82263-11-1

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ICAR- Central Marine Fisheries Research Institute (CMFRI), Kochi&
Asian Fisheries Society Indian Branch (AFSIB), Mangalore

Published by :

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Message

The President of India, Shri. Pranab Mukherjee, is happy to know that the 5th International Symposium on Cage Aquaculture in Asia (CAA5) is being held from November 25-28, 2015 at Kochi under the auspices of ICAR-Central Marine Fisheries Research Institute (CMFRI), Kochi, Asian Fisheries Society (AFS), Kuala Lumpur and Asian Fisheries Society Indian Branch (AFSIB), Mangalore.

The President extends his warm greetings and felicitations to the organisers and participants and sends his best wishes for the success of the Symposium

Deputy Press Secretary to the President

राधा मोहन सिंह
RADHA MOHAN SINGH

D.O. No. 2397 /AM

सत्यमेव जयते

कृषि मंत्री
भारत सरकार
MINISTER OF AGRICULTURE
GOVERNMENT OF INDIA

21st October 2015

Message

It is a pleasure to know that the 5th International Symposium on Cage Aquaculture in Asia (CAA5) is being organized by Cental Marine Fisheries Research Institute, Kochi, Asian Fisheries Society, Kuala Lumpur and Asian Fisheries Society Indian Branch, Mangalore during 25-28 November, 2015 at Kochi, Kerala.

The fish production in India that was just 0.75 million tonnes in 1950-51 is now 9.01 million tonnes, an increase of over 12 times. The production of inland fish is continuously increasing and presently accounts for nearly 2/3rd of the total fish production. Given the vast inland water resources in the country and backed by appropriate technological support, there is an ample scope for further growth of aquaculture, a sunrise sector.

Sea Cage culture is a recent technology in Indian coastal waters and CMFRI has developed the technology, promoted it through technical demonstrations and participatory approaches. CMFRI, Kochi has been involved in Marine Fisheries Research during the last seven decades since 1947 and has developed several mariculture technologies, which serve as livelihood option for coastal fisher folk.

I am sure, the Symposium will deliberate on key issues of cage culture, including, Production Systems, Breedng and Seed Production, Nutrition and Feed, Health and Environment Management, and Economics, Livelihood and Policies.

I wish the Symposium, a grand success.

Radha Mohan Singh

(Radha Mohan Singh)

Office : Room No. 120, Krishi Bhavan, New Delhi-110 001 Tel : 23383370, 23782691 Fax : 23384129

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CHIEF MINISTER
KERALA

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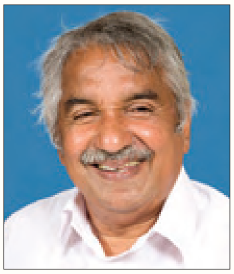

Message

I am glad to know that the 5th International Symposium on 'Cage Aquaculture in Asia' will be held from 25 to 28 November in Kochi and that a souvenir would be released to mark the occasion.

Harvesting of marine resources in its natural environment is facing too much competition and is leading to depletion of some of the popular varieties. There is a need for finding out ways by which we can enhance our seafood production. I hope that the international symposium on 'Cage Aquaculture' would meet its objectives and that its outcome would open up new avenues in aquaculture and allied activities. I also hope that the initiatives of ICAR-Central Marine Fisheries Institute with other national and International agencies would continue to make significant progress in the domain of aquaculture.

Wishing all success

OOMMEN CHANDY

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SECRETARY & DIRECTOR GENERAL

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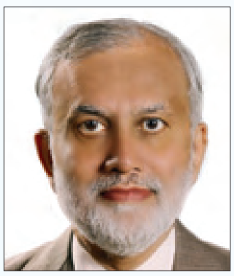

Message

It is a pleasure to know that the 5th International Symposium on Cage Aquaculture in Asia (CAA5) is being organized by Cental Marine Fisheries Research Institute, Kochi, Asian Fisheries Society, Kuala Lumpur and Asian Fisheries Society Indian Branch, Mangalore during 25-28 November, 2015 at Kochi, Kerala.

Sea Cage culture is a recent technology in Indian coastal waters and CMFRI has developed the technology, promoted it through technical demonstrations and participatory approaches. CMFRI, Kochi has been involved in Marine Fisheries Research during the last seven decades since 1947 and has developed several mariculture technologies, which serve as livelihood option for coastal fisher folk.

I am sure, the Symposium will deliberate on key issues of cage culture, including, Production Systems, Breedng and Seed Production, Nutrition and Feed, Health and Environment Management, and Economics, Livelihood and Policies.

I wish the Symposium, a grand success.

(S. Ayyappan)

सत्यमेव जयते

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Dated : 12th November, 2015

Message

It gives me immense pleasure to know that the Asian Fisheries Society (AFS), Malaysia is organizing 5th International Symposium on "Cage Aquaculture in Asia" from 25th - 28th November, 2015 at Kochi, Kerala, India.

Cage culture is yet to acquire commercial scale, so it is necessary that the technologies of cage culture are widely demonstrated for their large scale adoption by the enterpreneurs and governments.

I am certain that the International Symposium will orient the enterpreneurs toward cage culture so the fish production and productivity will go up in our country.

I wish the organizers all success

(K. N. Kumar)

CAGE AQUACULTURE IN ASIA
November 25-28, 2015 Kochi India

Asian Fisheries Society, Indian Branch
Mangalore - 575 001
Karnataka, India

INDIAN BRANCH

Dr. J. K. Jena
Chairman, AFSIB and
Incoming President, AFS

Message

The efforts of Asian Fisheries Society (AFS) in initiating specialized symposium series, other than Asian Fisheries Forum, with organisation of 1st International Symposium on Cage Aquaculture in Asia (CAA1) in Tunkang, Taiwan in 1999 was a significant milestone for the Society. It was not only a significant attempt in spreading the wings of AFS, but the Cage Aquaculture was also an appropriate subject which needed due attention for aquaculture system diversification in the region. The subsequent organisation of CAA2, CAA3 and CAA4 at Hangzhou, China in 2006; Kuala Lumpur, Malyasia in 2011; and Yeosu, South Korea in 2013 respectively could further provide appropriate platforms to disseminate the latest technologies and innovations pertaining to the cage aquaculture among the stakeholders involved in the industry in the Asia-Pacific region.

Known to be the most vibrant Branch of the Asian Fisheries Society, the Asian Fisheries Society Indian Branch (AFSIB), since its establishment in 1986 has been holding the Indian Fisheries Forum in every 3 years. AFSIB has also successfully organised the 8th Asian Fisheries Forum at Kochi in 2007 and 5th International Symposium in Gender in Aquaculture and Fisheries (GAF5) at Lucknow, India in 2014. In this endeavour, the effort of the Society in holding the 5th International Symposium on Cage Aquaculture in Asia (CAA5) in Kochi, India is another milestone in reaffirming its commitment towards scientific knowledge dissemination for overall growth of the fisheries sector in the region in general and in India in particular. Dr. A. Gopalakrishnan, Director of the ICAR-Central Marine Fisheries Research Institute (CMFRI) and Convener of the CAA5 and also his dedicated Members of the Organising Committee at CMFRI deserves applause for taking lead in organising the CAA5 at Kochi, India during November 25-28, 2015.

I sincerely wish CAA5 would provide an appropriate platform to showcase the research accomplishments and deliberate on the obstacles being faced on cage aquaculture in the region and come out with effective strategies for the sustainable growth of cage aquaculture, both in inland and marine sectors.

I, on behalf of AFSIB, convey Special Greetings to all the participants of the CAA5, Exhibitors and Members contributing to the organisation of the event, and wish the programme a great success.

(J. K. Jena)

Asian Fisheries Society
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Welcome Message

The Fifth International Symposium on Cage Aquaculture in Asia (CAA5)- Prof Shuolin Huang, President AFS

On behalf of the Asian Fisheries Society (AFS), it is my great pleasure to write this welcome message for the *Fifth International Symposium on Cage Aquaculture in Asia (CAA5)* to be held in Kochi, India from the 25th to 28th November 2015. The symposium is organized by the AFS, AFS-Indian Branch (AFS-IB) and the Central Marine Fisheries Research Institute (CMFRI) of the Indian Council of Agricultural Research (ICAR), India as the Convener and host. On behalf of the AFS, the Convener and the National and Local Organizing Committees CAA5, I wish to express my sincere welcome and thank you to some 200 and 50 participants respectively from India and Internationally from other overseas countries joining us in the symposium.

The CAA symposium is one of the most successful conference series held by the Society. This is the fifth symposium held by AFS on Cage Aquaculture since its inception some 15 years ago. It is therefore with great pleasure and pride that I write to congratulate the AFS-IB and CMFRI for convening and hosting the conference in Kochi, India. I am confident CAA5 will build on the past successes made by earlier symposia and deliver more information on technological development, production systems, improved feeds and environmental management on cage aquaculture in the Asia Pacicifc (AP) region.

Over the three day meeting, CAA5 will be focusing on five major topics:

- Production Systems
    - Potential Spceis
    - Grow-out
    - Site
    - Harvest
    - Design & Engineering

- Breeding and Seed Production
  - Hatchery Technology
  - Genetics
- Nutrition and Feed
- Health and Environment Management
- Economics, Livelihood and Polices

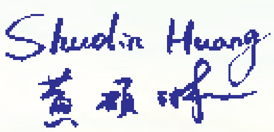
I am confident that many interesting papers with major and new ideas on cage aquaculture will be delivered and discussed as the industry moves forward. The world is facing increasing demand for fish on the one hand and increasing shortage of fisheries products on the other. Unless cage aquaculture farming system steps up its productioin through better R&D and technical innovations, the world is likely to face severe shortage of fisheries products and supply of fresh fish long before the middle of the 21st century. I therefore hope that there are many useful 'takeaway' ideas and technologies for participants attending CAA5.

Finally, it should be noted that the success of CAA5 is due to the combine efforts of many participating agencies and friends of AFS, CMFRI and AFS-IB in India. I would lke to express my sincere thank you to all of them, especially members of the National and Lcoal Organizing Committees for their support and contributions. Without the hard work from all of them, it will be very difficult to hold a successful symposium. Last but not least, on behalf of the AFS, I would like to express my special thank you to Dr. A. Gopalakrishnan, the convener, CAA5 and Director, CMFRI who has given his valuable time to manage and support the smooth running of the symposium.

Ladies and Gentlemen, once again, it is my great pleasure to welcome all fo you to CAA5 and to the beautiful tropical city of Kochi. I wish all of you active and successful deliberations over the next few days, After the symposium, relax and take a post-conference tour, enjoy the hospitality and the fine seafood and curry cuisines of the Kerala State.

Have a safe and pleasant journey back to you home after the meeting.

Good morning and thank you for your participation.



Professor Shuolin Huang
President
Asian Fisheries Society (2013-2016)
9th November 2015

FOREWORD

An ever-increasing population and subsequent demand for healthy, affordable protein have placed a tremendous strain on fishery resources worldwide. With most wild fish stocks already at or beyond sustainable levels of harvest, aquaculture presents the most viable means of meeting global demand. While intensive aquaculture has been practised successfully in many parts of the world, much of it is land based, and therefore restricted to freshwater or brackish water species. Large freshwater reservoirs and near-shore coastal waters in Asia represent areas with immense, mostly untapped, potential to improve fisheries production via cage aquaculture- the farming of aquatic animals in suitable enclosures anchored in open waters.

Several factors affect the success of cage aquaculture. The identification of suitable sites, cage design, the production and availability of seeds and the availability of nutritionally complete feeds are critical to the establishment of operations. The control of pathogens and infections as well as understanding and minimising environmental impacts are essential to ensure long term sustainability. A strong legal framework is also essential to protect rights of access to water bodies and ensure fair use while also considering the environment and socio-economic impacts.

The 5th International Symposium on Cage Aquaculture in Asia (CAA5); being organised by the Asian Fisheries Society and the ICAR-Central Marine Fisheries Research Institute (CMFRI), in association with the Asian Fisheries Society- Indian Branch, from the 25th to 28th of November 2015 at Kochi, India, presents an opportunity for scientists, policy makers and fish farmers from around the world to review the state of cage aquaculture, learn from past experiences and set milestones for growth.

This souvenir is a compilation of invited manuscripts distilling lessons learnt over decades of cumulative experience in marine and inland cage farming, breeding and seed production, nutrition, health and environment management, legislation and policy issues. I congratulate the organisers of the Symposium for facilitating this exchange of knowledge and ideas. I also thank the contributors for giving freely of their time and expertise. I hope the experiences shared here will contribute to the future success of cage aquaculture in the region and go some way towards ensuring food and economic security.

A.Gopalakrishnan
Director CMFRI & Convenor CAA 5

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5th International Symposium on

Cage Aquaculture in Asia - CAA5

Cage Aquaculture for Food, Fortune and Future

November 25-28, 2015, Kochi, Kerala, India
Radisson Blu Hotels & Resorts

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Enhancing Coastal Fish Production through Mariculture and Sea ranching
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Improving Coastal Livelihood

_Symposium Theme Lecture, CAA5__. 25 Nov. 2015_

Greening the Asian Cage Aquaculture Construct

Prof. Mohan Joseph Modayil

World aquaculture production (2013) was to the tune of 97 million metric tons worth USD 157 million, contributing to 43% of total world fish production. That Asia contributes to over 90% of aquaculture fish production of the world undoubtedly establishes the primacy of the fish farmers of Asia in addressing the food and nutritional security of fish mongers of planet Earth. The dominance of the Asian region is anchored upon the congenial climatic conditions and ecosystem diversity of the water bodies, availability of numerous andidate species, warm temperatures resulting in faster growth, high productivity of waters, entrepreneurship of fish farmers, reduced cost of inputs including labour and the ever increasing demand for fish.

Nevertheless, aquaculture in the Asian region does not present a rosy picture to those looking at it from outside the bandwagon. During the past few decades, emergence of cage aquaculture as a promising activity across many parts of the world has resulted in added interest in the diversified production system and had yielded interesting results in many countries.

Cage aquaculture fascinated me a decade back after my visits to the mainland China where I had opportunities to visit numerous cage farming sites and interact with local farmers through interpreters and understand the ground realities of the farming practices. After my return to India, with the special funding from the Ministry of Agriculture, I could initiate the first ever open sea cage culture in India with Sea Bass fingerlings in Visakhapatnam with the prime objective of demonstrating the feasibility of open sea cage farming in Indian seas. Before this pioneering work, MPEDA had already started inland pond based cage aquaculture in the south east coast of India. There were also some attempts elsewhere to establish cages in reservoirs to grow carps. Subsequent efforts by MPEDA, CMFRI, CIBA, CIFA, CIFRI, State Departments of Fisheries and others have made progress and currently these efforts are being taken up by several farming communities, some supported by the state fisheries departments, across the country. Thus, it is the most appropriate time to organize the 5th international cage aquaculture symposium in India where the farming communities are fast adopting the concepts and practices of cage aquaculture. This will give an opportunity to share experiences and understand the developing technologies, trends, issues and constraints across the Asian region.

The hallmark of the Asian region is its diversity which is reflected everywhere. This is explicit in the area of cage aquaculture also by virtue of the species diversity of cultured species, the habitats, the variety of designs in cages, the techniques employed, feed management, harvesting patterns and market practices.

The history of modern cage aquaculture in Asia is rather short. Freshwater cage aquaculture is believed to have originated in the Asian region first in the Mekong basin countries, but has developed into all water bodies and is extremely diverse in nature with varying types of cages in structure and design, species cultured, feeding and management and husbandry practices, and intensity of operations. Stand alone to cluster of cages are seen in freshwater bodies with varying designs and materials. Massive quantities of fish are produced in these regions using cage farming of species such as Pangasid catfishes. In the Indonesia, combinations of common carp and tilapia are farmed in cages. In the seas, cages of hanging type (lantern net cages) are in vogue in many places such as Korea for culturing bivalve molluscs. Such cages are also used in Japan, China, and south Pacific seas for pearl oysters and abalone. Large floating cages are of recent introduction in the Asian region. Many seas, for example the south China sea and Japanese waters, are prone to cyclonic storms and open sea cages are most vulnerable, a fact which limits the spread of cages in many places. The last 45 years have seen the introduction and rapid spread of the Norwegian type of cages in south east Asia and China. Presently, 95% of marine finfish farmed in Asia are from open sea cages, brackish water cages and cages deployed in creeks and inshore waters. There are about 80 species of fish currently farmed in the Asian region, common ones being Asian seabass (*Lates calcarifer*) and the milkfish (*Chanos chanos*), amberjacks (*Seriola* spp.), snappers (*Lutjanus* spp.), groupers (*Epinephalus* spp.) and cobia (*Rachycentron canadum*). In India, currently cage farmed species, the Asian Sea Bass, Cobia, Milk fish, Lobsters and Pompano although in very small quantities only in a few maritime states.

China has extensive open sea cage units. Chinese cage aquaculture started only in 1970. In the early years, it was only on artisanal scale, but by 1980, it expanded to commercial scales. In the late 1970s, Huiyang County and Zhuhai City, Guangdong Province tried to grow marine fishes such as groupers and seabream in cages. Beginning in 1984 other counties and provinces (e.g. Fujian and Zhejiang provinces) also began to grow marine fish in cages. In the 1980s, the number of marine fish cages in the three provinces of Guangdong, Fujian and Zhejiang had exceeded 57,000 and more than 40 species of marine fishes were farmed. Currently, over 1.5 million cages are deployed in the coastal waters of China.

Myanmar has cage aquaculture of several species such as the Groupers *Epinephelus malabaricus, E. bleekeri, E. tuvina* and Sea Bass *Lates calcarifer*. However, all the seed come from wild. Thailand grows 4 species of Groupers *Epinephelus coioides, E. malabaricus, E. fuscoguttatus, Plectropomus maculatus,* 2 species of snappers *Lutjanus argentimaculatus* and *Lutjanus* sp. and the Sea Bass *Lates calcarifer*. Also grown are the Square tailed Mullet *Liza vaigensis*. Malaysian cage farming has species such as *Lates calcarifer, Lutjanus argentimaculatus, L. lemniscentus, L. johnii, L. erythropterus,* Groupers *Epinephelus coioides, E. malabaricus, E. sexfasciatus, E. fuscoguttatus,* Travelly, Pompano, Cobia and Tilapia. In Indonesia, several species such as the milk fish *Chanos chanos,* Sea Bass *Lates calcarifer*, Groupers *Cromileptes altivelis, E. fuscoguttatus, E. polyphekadion, E.*

coioides are extensively farmed.There is a strong hatchery production system for most species in Indonesia, thanks to the oceanic waters and ecosystem providing many suitable species for broodstock. *E. fuscoguttatus, E. coioides, and Cromileptes altivelis* are all hatchery produced. Most of the hatcheries are small and private, with low survival rate; however the high fecundity of the species used make the hatcheries very profitable in operation. Even Vietnam cage aquaculture is extensive, but much of the seed comes from wild sources. Eleven marine species such as *Epinephelus coioides, E. tauvina, E. malabaricus, E. bleekeri, Rachycentron canadum, Lates calcarifer, Psammoperca waigensis, Lutjanus erythropterus, Rhabdosargus sarba, Sciaenops ocellatus* and *Siganus* sp. are grown. Hong Kong has a very vibrant live fish market fuelling widespread interest in cage aquaculture. Species grown include *Epinephelus tauvina, E. chlorostigma, Rachycentron canadum, Lutjanus russelli, L. argentimaculatus,* White blotched Snapper, Head Grunt, Crimson Snapper, Gold lined Sea Bream, Japanese meagre, Pompano, Red Drum, Black Porgy and Yellow fin Sea Bream. In Japan scallops, abalone, oysters and seaweeds are grown in net cages. Finfishes such as Yellow Tail, Blue fin Tuna *Thunnus thynnus*, Barfin flounder *Verasper moseri, Epinephelus* spp are the main species in cage farms. Taiwan province of China has over 2000 hatcheries operating in a value chain fashion, some developing broodstock, others breeding fish, yet others developing the nursery stages while several others focussing on the grow-out. The main species are *Epinephelus coioides, E. lanceolatus. Trachinotus blochii, Lutjanus argentimaculatus. L. stellatus, Acanthopagrus latus* and Cobia. Korean cage farms focus on *Pleurogrammus azonus,* Bastard Halibut *Paralichthys olivaceus, Mugil cephalus, Epinephelus septemfasciatus, Seriola quinqueradiata, Lateolabrax japonicas, Chrysophrys auratus, Stephanolepis cirrhifer,* fishes of family Scorpaenidae and Korean Rockfish *Sebastes schlegelli.* Extensive culture of bivalves from lantern net cages from long lines is hallmark of south Korea. In the Philippines, milk fish is an important component of the aquaculture system. The bulk of the production is from freshwater and brackishwater grow-outs, the marine cages contribute to about 12 to 15% on the total production. Much of the produce is locally used, as the areas are wide apart, market dynamics are difficult and lack of coordinated efforts for marketing, technology transfer and back stopping and poor export linkages.

Australia, New Zealand and the Oceania started cage farming as early as the 1980s. The Atlantic Salmon *Salmo salar* culture was initiated in Tasmania, followed by the Chinook Salmon *Onchorhynchus tschawytscha, Southern* Blue fin Tuna Thunnus *maccoyii*, the Sea Bass (Barramundi) *Lates calcarife,* the Yellowtail Kingfish *Seriola lalandi,* Tilapia and carps which are the dominant species. The countries in the Oceania such as North Marianas, Marshall Islands, Micronesia, Palau, Hawaii, French Polynesia, Solomon islands, Nauru, Papua New Guinea, Pitcairn, Niue, Tonga, Samoa, Cook islands, Tokelau, Fiji, Kiribati, Tuvalu, Wallis islands, and Vanuatu have cage grow-out systems for several species including Tuna, Barramundi and Salmon. Much of these are grow-out systems owned by private players with industrial interests. Australia and New Zealand have strict regulatory measures for cage farming as well as for collection of wild seed.

In my talk today, I wish to focus attendtion to issues on sustainability and inclusiveness of Asian cage aquaculture scenario, without further going into the review of Asian cage aquaculture. Asia is the largest multispecies cage aquaculture production hub with over 80 marine species and about 20 freshwater species being farmed. So it is a massive activity across the Asian region. However, I am of the view that cage aquaculture by being strongly intensive can not support the objectives "supplementing capture fisheries, poverty alleviation, livelihood, rural food and nutritional security, feeding the millions, *etc*". This hype is only populist jargon and we all have heard enough of these. In my opinion, these are not the drivers of cage aquaculture. The real objective and outcome of cage aquaculture, which none is willing to openly admit, is "business" which means entrepreneurship, profitability. I am of the considered opinion that cage aquaculture in developing Asian countries is only a business opportunity to whomsoever it may concern, they be farmers, fishermen, entrepreneurs or industry. Of course, there are secondary business development, employment generation, improved living standards, additional income, allied industries, all contributing to the welfare of the people in this and related activities. These are only fall outs. The unregulated spread of the new initiatives across the Asian region is bound to boomerang just as the shrimp aquaculture did in the past.

There are well structured regulatory systems and guidelines for cage aquaculture in some of the Asian countries. Guidelines and regulations in Norway, U.K. Faroe islands, USA. Japan, Australia, New Zealand are good examples. However, in the Asian countries either the regulations are weak, un-implementable or absent. In such a situation, it is imperative for those concerned to look beyond production and design frameworks to make the Asian cage aquaculture responsible, sustainable and inclusive.

Therefore, I have questions to ask. Currently there are about 80 or more marine species and about 20 freshwater species grown in cages in the Asian region. As a strategic region providing 90% of farm grown fish to the world, there is urgent need for regional planning, monitoring and greening agenda. Why are we doing cage aquaculture at the cost of fishery resources? Who benefits? Is the technology used viable, resource and environment friendly? Is there an equitable share of profits for all players? Are all our present practices "green"? Are these technologies sustainable, safe? Are they environment friendly? Are they economically viable in the long run? Are they inclusive? Do these practices destroy the resource resilience? Do they affect the biodiversity balance? Do they affect the trophic structure? Are there dangers of introduction / escapes and spread of non-native species? Are there dangers of introduction of native or alien virus, bacteria, parasites, diseases in intensive culture systems? Is it not a priority to address these questions first and take a holistic view, rather than sweeping uncomfortable questions under the carpet and going ahead with limited agenda of the operating agencies? How do we make our current cage aquaculture practices GREEN?

Today we have the cream of Asian cage aquaculture scientists and entrepreneurs here in this hall. As individual countries we have our own agenda and priorities. However, without forgoing these, could there be a meeting point with a common agenda to make the respective cage aquaculture constructs GREEN? How do we address some of the common concerns?

When we are in the driving seat, the vision is the road ahead, the destination. In cage aquaculture the sole objective is to produce more fish. We fail to see the rear view, the impact. We fail to see the side roads, the others who are traveling, the damages caused, and the macro scenario, to look beyond. We feel that what we do is right, if anything is wrong, it is for others to make corrections.

Cage aquaculture originated as an industrial activity in the 1960s with the success demonstrated by the Norwegian initiatives, followed by other European countries. The early success in Norway prompted development of salmon grow-out in cages in Scotland, Ireland, Faroe islands, Canada, North East USA coast, France, Spain, Australia and New Zealand. It aims at producing large quantities of fish by holding them in controlled cages and through supplementary feeding and grow-out management. In the Asian region, China, Taiwan, Japan, Vietnam, Indonesia, Australia and Oceania are the major players. The objectives and priorities of each country may vary; however, the ultimate objective is entrepreneurship and profitability. Except in experimental stages controlled by government laboratories or departments, all cage aquaculture production is in private hands. When profit is the driving force, many other areas are often neglected.

Who benefits? We have heard enough of the so called drivers of cage aquaculture, such as supplementing capture fisheries, poverty alleviation, employment generation, food and nutritional security, *etc.* which all are nothing but key words for attracting interest or funding support or governmental subsidies. Cage aquaculture is certainly not going to address any of the above directly. The greatest benefit in the form of profits lies in between the farm gate and the consumer's table. Is there other benefits, these are all fall out of cagefarming. Are there equitable share of profits for all players? The answer is no in most countries. This is one reason why many Chinese farmers are signing off. They are no longer able to enjoy the benefits and profits they once enjoyed from open sea cage culture. Still, many of them survive because of the high price for live fish they get from export markets.

Where and how the sites are chosen? There is a tendency to project the cage aquaculture potential in relation to the length of the coastline, presence of creeks, lagoons *etc.* and postulate high growth opportunities for this activity. This is not true in reality. First, the topography and extent of the coast are not the only criteria for locating the cage farms. There are numerous factors to be considered including the depth, currents, water quality, impact to the environment, traditional rights of the users, domestic and industrial effluent discharges, nearness to cities and towns, present and future developmental agenda of the government and industries, water body partitioning master plans, threatened ecosystems, security and ease of operations, boating and shipping channels, nearness to live fish market or processing facilities or markets and a plethora of related factors including public perceptions. Many Asian countries have relatively shallow waters which provide extensive open sea areas. However, the threats of cyclones and heavy storms are factors limiting the operations. Also countries such as Indonesia, the Philippines, other island nations of the Indo-Pacific have extensive coral reef ecosystems which are ideally left free without human interventions. India, has rather deep coastal waters and strong wave action in the western seas, while on the eastern marine reserves, coral seas and shallow waters limit the actual availability of sites suitable for laying cages. There are guidelines and master plans in many of the developed Asian countries which prescribe the norms for establishment of cages and for licensing of the activity. Others in Asia are yet to frame such guidelines and policies. The duty of the researchers and research organizations is to sensitize and advise the respective governments for developing and implementing such policy guidelines so that cage aquaculture development is planned, sustainable, environment friendly, monitored and regulated to safeguard all concerns. Most scientists and governments appear to be unaware of the impacts and adverse effects when they are able to see only increased production as the objective of cage aquaculture. We need to take lessons from the past story of shrimp aquaculture in Asia and present another disaster which can much more serious as it is carried out in the open seas and much greater geographical extend.

Are the grow-out systems Green? There are many types of cages and production systems available today, starting from the traditional fixed artisanal cages to modern floating cages, semi-submerged cages, fully submerged cages, towing cages, all in varying shapes and sizes. A great deal of engineering skills has gone into the design and erection of advanced cages which are established as part of cage aquaculture industry. These cannot be compared to the types of cages and scales of operations where small farmer groups and entrepreneurs are involved. Industrial cages have more impacts if they are concentrated in same area, such impacts are complex and massive. Even large numbers of small floating cages also can result in many adverse impacts. The adverse impacts on the environment are rather well known, but poorly addressed. The dangers of cage aquaculture in sensitive and threatened ecosystems such as coral reef habitats, mountain streams, island ecosystems, marine reserves are also not well addressed. Damage to the local biodiversity is another aspect to be understood and addressed. This can happen starting from the very process of establishing the cage farms to dangers of escapes of undesirable species, introduction of predators, introduction of parasites, virus and diseases, collection of wild seed and genetic pollution from escapes.

What is the source of broodstock? Developing and maintaining healthy broodstock is an essential prerequisite for a well-managed cage aquaculture system to ensure steady supply of adequate quantities of fingerlings to farmers. Certain species of groupers (mostly genera *Epinephelus* and *Mycteroperca*) are monandric protogynous hermaphrodites, *i.e.* they mature only as females and have the ability to change sex after sexual maturity. Some species of groupers grow about a kilogram per year and are generally adolescent until they reach three kilograms, when they become female. However, some other groupers are gonochoristic. Gonochorism, or a reproductive strategy with two distinct sexes, has evolved independently in groupers. Captive breeding of such fishes may pose problems and long term efforts may be needed for successful hatchery techniques. Also, selective removal of large sized Grouper from the wild population for live fish export market as practiced in the Andaman & Nicobar waters is a threat to the ecological balance and breeding potential of the wild stock which along with intensive collection of grouper seed from wild will have long term adverse impacts on the resources.

Are the seed sources Green? Ideally the source of seed for the cage aquaculture must come from hatcheries as practiced in most countries like China, Taiwan and Australia. However, collection of fish seed from wild is a common practice in many situations where hatchery supply is not there or is inadequate. It is alarming to note that even responsible institutions have been recommending for increasing the efforts for collection of wild seed without realizing the consequences on the biodiversity, species not used for cage aquaculture and the stock health. Basic understanding of the larval biology and ecology is essential before venturing into wild seed collection. Capture based aquaculture is only semi-aquaculture in the true sense, perhaps even comparable to tuna fattening in cages which is not considered as cage aquaculture. It is understandable that some species are difficult to be bred and wild seed is an alternative available. While considering wild seed collection, it must be understood that there are two types of species groups with varying situations for the larvae between hatching and entry in to the fishery (recruitment). In one situation, the hatchlings are abundant and during the course of its early larval life which is a critical period, most of them die due to many factors including food availability and a factor called density dependent mortality. This results in survival of only a few larvae to young adults. In such cases, collecting the wild seed which arein the early stage of development is reasonably justified as otherwise most of them will anyway die in their early life. If collected and nurtured, then these seed can be saved from perishing from natural causes and can be grown to adults. No harm will be done to the resource resilience in such cases. However, such basic information on larval ecology is not available for most species in the Asian Region. In the other type of species group, in the early larval life, when most of the hatchlings survive between hatching and recruitment and the density dependent mortality is low, removal of the wild seed upsets the natural balance in the foodweb because almost all of them would survive and become adults and play their roles in the foodweb. Selective removal of a segment of the food web is detrimental to other components of the system and therefore must be avoided. These facts must be well understood before publicising the idea for making recommendations for wild seed collection. In countries such as Australia and New Zealand, collection of wild seed is not permitted. But development of hatchery is an expensive R&D affair, and therefore before investing in hatchery, the feasibility of grow-out must be tried and process established. Thus blanket ban on collection of wild seed is not conducive to development of hatchery at least in the early stages of cage farming development. Many responsible institutions suggest capture based aquaculture (CBA) without realizing the rationale and argue that CBA enhances marine fish production and reduce wastage of resources as low value bycatch is used up as feed for production of high value farmed fish. This argument has not many takers. Across the world, use of bycatch for feeding farmed fish is being discouraged and the responsible aquaculturists, we need to prevent this abuse of fishery resource. For long term sustainability, the seed supply should follow the green guidelines so that anthropogenic interferences do not adversely affect the foodweb and the wild stock.

There is a praiseworthy practice followed in countries like Thailand, Indonesia and Taiwan where a portion of the millions of fertilized eggs or hatchlings from a single spawning are supplied to farmers for rearing them in private farmer owned backyard nurseries who later stock them in cages. This is one reason why cage farming has spread extensively in these countries. China also obtains a great deal of seed from imports. This is an excellent model which can be adapted in other countries where many hatcheries cannot be set up for various reasons. Farmers can be trained to rear the larvae in backyard nurseries and feed the larvae with formulated feed right from juvenile stage. This will also help in reducing the use of trash fish in feeding cage farmed fish. Small scale hatcheries in Indonesia shift breeding from one species to another depending on market demand, prices and economics. Establishing such multipurpose small scale hatcheries and/or adapting the remote nursery model along the coast could be an ideal alternative for India for extensive development of cage farming in the country.

Are our present feeding practices Green? Cage aquaculture using trash fish as feed is not a green practice and therefore this practice should stop forthwith. One criticism against aquaculture is that its growth is a direct threat to the wild fish resources. This is because of the use of wild caught fish as feed as well as the use of large quantities of fishmeal from marine biodiversity resources including fish. Biodiversity destruction is the immediate fall out of cage farming. Both direct and indirect impacts are well known. The first step for making cage aquaculture green is by addressing the threats to biodiversity. There are organizations promoting cage aquaculture and predicting tens of thousands of tons of fish production from cage farmed fish fed by low value fresh or frozen fish. One statement from India predicts production of 1,0000000 tons of fish produced through cage mariculture by feeding them with low value trash fish. Under the Indian conditions, 3.3 kg of pelleted feed or 9 kg of trash fish are needed to produce 1 kg of cage farmed fish. If such a projection has to become a reality, then we need 3.3 million tons of formulated feed or 9 million tons of trash fish. When the total marine capture fisheries production from the country is only 4million tons, how are we going to feed the cage farmed fish with 9 million tons of trash fish? If pelleted feed are used, at moderate estimate of cost of feed at Rs. 35 per kg, we need Rs. 11.55 crores for feed and Rs. 7.7 crores for over heads. So where is the profitability unless farm gate price of fish is over Rs. 500 per kg.? Imagine also the adverse environmental impacts such massive operations cause to the ecosystem. Such unrealistic projections can be misleading for the farming sector and adversely impact the credibility of organizations responsible.

Is the cage culture practice sustainable and resource/environment friendly? Impact of cage farming on environment is a topic which has been extensively dealt with. Wherever there is human interventions with natural systems, adverse impacts are certain. Intensive culture in cages has caused eutrophic situations in many grow-out areas. Outbreaks of red tides are common in the Asian region which can affect the cultured fish and can result in total loss. Therefore, the objective is to minimize such adverse impacts rather than ignoring them. If the practice has to be sustainable, we need to consider all aspects of sustainability. Modern aquaculture practices are largely unsustainable as they consume natural resources at a high rate. Intensive aquaculture cause extreme environmental pollution and result in disease outbreaks. In many countries cage aquaculture uses either low value fish or formulated feed which has a high input of fish proteins and oils. The idea of producing carnivorous fish such as salmon, sea bass, tuna, various perches, eels and other species on a diet rich in fish meal and oil makes commercial sense, as the farmed fish fetch a much higher market price than the fish ground up for fish meal or chopped and thrown into the cages. However, most of such low value fish in the tropics are livelihoods of small enterprise opportunities and cheap food-fish for coastal poor in the Asian countries. This certainly adds pressure on the wild stock and affects natural recruitment in the seas. Therefore the efforts should be to produce fish using efficient and cost-effective methods to improve the life of human beings while judiciously utilizing and conserving available resources and protecting the environment.

Are they economically viable and inclusive? Economic viability is a relative term. What is economically viable in one country may not be viable in another. Taking into consideration the prevailing prices of components, labour, depreciations and market fluctuations, the economic viability will have to be worked out for each culture system, place and species based on actual field results. Economic analyses made by certain institutions are far from real situations and have no consequence. Even the survival rate calculated or the production figures projected are far from reality. Studies have shown that survival in cages in the Asian Region is about 40%. Independent commercial production figures are to be generated by independent agencies to arrive at the actual situations. In the unorganized sector such as small scale fish farming, the producer gets only a marginal profit while the real profit lies between the farm gate and the consumer's table. When the production is massive and the harvest is not staggered and without proper value chains, the price realized will be less than the wild caught fish price. When the supply chain is well established and the market is vibrant, for example the live fish market in Taiwan, Hong Kong, China, Thailand and Singapore, the fish has fancy prices and the whole operation is very remunerative. But this cannot be realized across the Asian countries, unless proximity between the places of grow-out and the consumer market is near so as to allow live fish transport and holding. Economics of Salmon or Tuna farming (= tuna fattening) is quite different as they are part of well-established value chains catering to the needs of affluent discerning consumers. Inclusiveness in cage farming is currently limited to the labour inputs by the farmers and labourers. Except in the case of traditional cage farming practiced in parts of Lao PDR, Cambodia, Vietnam, modern cage farming is capital intensive and not affordable to Asian fish farmers who do not have the economic backing. Governmental incentives and subsidies to a great extent support much of fish farming activities in countries such as India. The produce from cage aquaculture is targeted at a niche domestic market and can be made profitable with proper market chain. However, making such operations inclusive in the real sense is only wishful thinking. Much of the inclusiveness is restricted to labour wages and other fall outs. If cage culture practices are taking away small pelagics which form the livelihood and or food fish of coastal poor, the practice can never be considered inclusive.

Do these practices destroy the resource resilience? As already discussed, aquaculture *per se* is a resource unfriendly activity, be it pond based or cage cultured. Impact on biodiversity is many sided, from wild seed collection, destruction of biota at farm sites, upsetting the trophic chain, use of wild caught fish for fishmeal, fish oil or as bycatch wet fish food. Since feed cost is the major recurring cost in cage farming accounting to as much as 50% of total costs, and feed cost is decided by the source of protein which is currently fish meal, efforts must be on for finding viable alternatives. Use of fish processing factory waste is a viable option for some limited quantities. Poultry by-product meal, meat and bone meal, feather meal, blood meal, soybean meal, cotton seed meal, Rapeseed meal *etc* have been used as part of protein source in fish feed. Such efforts will reduce the quantities of fishmeal in the diet and reduce not only the cost of the formulated feed, but also reduce the pressure on the wild resources as well as reduce the ever increasing demand for fishmeal. However, the adverse enviornmental impacts of the residual feeds and wastes from cages is yet another aspect not fully realized. Green cage farming has to look into this aspects and design strategies to cope with the environmental damages of this impact. The recent efforts of some organizations to come with substitute to reduce the fish meal content in the feed are praiseworthy. A new sustainable fish feed ingredient that can reduce the aquaculture industry's reliance on fish meal in likely to be launched in 2018 by California based Calysta Inc. The product called FeedKind™ Protein is a non-GMO high quality microbial protein that provides a cost effective alternative to fish meal, approved by the EU for all fish and livestock feeds. Such innovations are the game changers for aquaculture industry and will usher in a sustainable and healthy development of the industry.

Are there dangers of introduction / escapes and spread of non-native species? Many countries have strict rules regulating or preventing introduction of alien species for aquaculture. In spite of such bans, many Asian countries have several alien species introduced and such introductions are continuing. When such species are introduced, there will be continuous threat of them escaping to local ecosystem and upsetting the balance, predating upon native species and often introducing parasites, bacteria and virus. The likelihood of genetic pollution of native stock is very serious and there is need for research and analysis and impact evaluations.

Are there dangers of introduction of native or alien virus, bacteria, parasites, diseases in intensive culture systems? A classic example of dangers of introduction of alien virus to the ecosystem is the mass mortality of native Pilchards in the Australian waters from the suspected virus introduced from imported frozen wet fish used as feed for cage farmed Bluefin Tuna. Such dangers do exist in all systems where wet feed made out of low value bycatch is used as feed. Currently in Australia, only formulated feed are used for all cage farmed fish except Tuna, for which a massive research programme is on for developing formulated feed. Use of bycatch for feeding cage farmed fish has to end, the earlier the better in all parts of the Asian region for several reasons which are now explicit to all. Governmental regulations must be brought into place in the Asian countries for making this happen and scientists and organizations in the region has a major responsibility in ensuring full compliance in their home countries. Conferences such as the present one should not only flag these issues, but also use these opportunities to convey the message to the farming countries in the interest of conservation of the over exploited marine fishery resources as well as for ensuring long term sustainability of cage aquaculture.

Way forward

Establishing guidelines, rules, regulations and safeguards is the first and foremost need of the sector in all the Asian countries where such policy frameworks do not exist. This includes all aspects from site selection, land / water area planning, licensing, lease rights, insurances, traditional rights, common property user rights, wild seed collection, pollution of the environment, genetic pollution and issues related to escapes, introduction of exotic species, quarantine protocols, regulations against use of wild caught fish for stocking, use of bycatch for feeding, development of small hatcheries and nurseries run by farmers, supply chain development, application of polluter pays principles, subsidies for good management practices, preventing use of chemicals and antibiotics, value addition, marketing linkages including cold chains, conservational mariculture, technology back stopping for small farmers, training and awareness programmes. Rather than encouraging vertically integrated large scale industrial cage farms, support for fisher owned small scale resource and environment friendly farms with local fingerlings obtained from local hatcheries or nurseries will make the practice resilient and remunerative to the primary producers. Offshore large farms are not likely to be the answer for cage aquaculture in Asia. Clusters of well managed small farms with farmer participation and technological back stopping from mandated institutions will be the game changer for Asia which will continue to remain the major aquaculture fish producer of the world. Both constraints and opportunities of the Asian scenario will continue to regulate and develop cage aquaculture in the Asian region and the diversity in species, ecosystems, culture practices, culture methods and incentives for growth shall help Asia to contribute significantly to global production of cage farmed fish.

The emerging era is one of safe and responsible food production with traceability and certification controlling the opportunities. Responsible and safe aquaculture will continue to grow and flourish while other systems and practices will gradually fade away. The CAA5 is the fifth in the series of cage aquaculture organized by the Asian Fisheries Society and this is the right opportunity in time for all Asian cage aquaculture nations to come together and resolve to work by sharing experiences and expertise towards ensuring safe and responsible fish production for the world population. Such conferences should not remain as avenues for discourses of science and technology, but also as opportunities to find solutions and work together towards common goals in the sector to attain sustainable growth. Both AFS and NACA have responsible and increased roles to play in this area. While departing after this conference, the single thought to take home in your minds should revolve around the way forward for greening your country's cage aquaculture and what you can do about it. Three years from now when we meet at CAA6, we should be able to hear from you the great strides your country has made in this direction. Till then, good bye and safe, responsible aquaculture.

Thank you.

Mariculture research towards a sustainable blue revolution in India

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Mariculture involves the cultivation of marine organisms in seawater for food and other products either in the open ocean, an enclosed section of the ocean, or in tanks, ponds or raceways. About 600 aquatic species are cultured all over the world in a variety of farming systems and facilities of varying input intensities and technological sophistication. Mariculture activities other than for human consumption include live bait farming for fishing, live ornamental animal and plant species and ornamental products (pearls and shells), fishes cultured as feed for certain carnivorous farmed species, culture of live feed organisms such as plankton, Artemia and marine worms for use as feed in hatcheries and grow-out systems, aquaculture hatchery and nursery outputs for on-growing in captivity or stocking to the wild and capture based aquaculture. Asia accounted for 89% of world aquaculture production by volume in 2010, up from 87.7% in 2000. Mariculture represents an opportunity to provide a sustainable supplement to the marine capture fishery. Mariculture has a relatively long history, while, the modern intensive mariculture is only 35 years old, producing a steadily increasing proportion of the world's seafood during this period. Aquaculture production currently makes up almost half of the marine capture fisheries. Moreover, aquaculture production has more than doubled over the last fifteen years and this trend is continuing whilst traditional fishing production is declining as a result of over exploitation. But aquaculture, both in inland waters and marine and coastal areas, has problems, including habitat degradation, disruption of trophic systems, depletion of natural seed-stock, transmission of diseases, and reduction of genetic variability. To solve these problems it is needed to diversify aquaculture and improve its sustainability. In particular, we need to better understand possible interactions between mariculture and natural environments to minimize the potential for habitat degradation, introduction of invasive alien species, etc.

The ICAR-Central Marine Fisheries Research Institute (CMFRI), the premier marine fisheries research institute in India has been taking up active interest in mariculture since its inception in 1947 and many technologies have been developed by the Institute during the past six decades. The earlier investigations were mainly directed to obtain the basic information on the biology of the cultivable species and on the environment in which they live. At a later stage, increased awareness on the importance of mariculture in augmenting fish production and improving rural economy has provided greater emphasis and thrust on mariculture research by CMFRI. The need for mariculture in India was emphasized by CMFRI in 1952, by advocating the conversion of low-lying areas along the Indian coast, which yield nothing, into fish farms. Although a variety of marine organisms suitable for culture were available in the country, the initial investigations were mostly concentrated on shell fishes (molluscs and crustaceans) in view of their greater economic importance at that time.

Mussel farming became the main focus for mariculture during the seventies. In 1975, culture of green mussel in the open sea at Kozhikode employing raft-culture techniques was taken up and the production rate for a period of 5 months amounted to 235 tonnes/ ha. The technique of rope culture was yielding 150 tonnes of mussels/ha/year at Vizhinjam near Trivandrum (Achari, 1975). Culture of green mussels on rafts in the open sea at Kovalam near Madras also yielded commendable results. Commercial mussel farming gained rapid strides since 1996 in India. In the recent years mussel farming showed spectacular improvements with the farmed mussel production of the country reaching a total of about 20,000 tonnes. Though efforts to popularize the technology were undertaken in the States of Kerala, Karnataka, Goa, Maharashtra and Tamil Nadu a quantum leap in the mussel production was observed only in the state of Kerala mainly due to the preference of mussel meat in Kerala. The availability of large extent of natural mussel beds along the Indian coast for sourcing the seeds, high price realized for the produce in domestic market, minimal operational expenditure and short term eco-friendly farming techniques are all positive note for more farmers to adopt the practice in future years.

One of the remarkable contributions of CMFRI which made to promote mariculture in our country was the successful development of the techniques of pearl production under controlled conditions. Researches leading to this achievement were started in 1972 using pearl oyster *Pinctada fucata* cultured by the raft culture method and by artificial nucleus implantation. On shore pearl production was also attempted and made successful.

CMFRI had taken up investigations on edible oyster *Crassostrea madrasensis* culture in late 1970s. The techniques of oyster culture includes collection of spat and growing them to marketable size by different methods such as rack culture, long-line culture, pole culture and tray culture. Farming is not widespread in the country and that practiced on a very small scale at certain locations in Kerala also requires to be expanded. The two major concerns which have to be addressed are the low value- high volume production of spat to cater to the seed requirement and the development of suitable marketing channel. Culture of the backwater clam, *Meretrix casta*, was initiated at Porto Novo in Tamil Nadu and at Buminipatnam in Andhra Pradesh and that of cockle, *Anadara granosa* at Kakinada in Andhra Pradesh. As such no commercial farming for any of these species are prevalent in the country.

CMFRI has carried out a series of demonstrations on culture of marine prawns with a view to transfer the technology developed by it to the actual farmers and to promote prawn culture on scientific lines during 1970s. The result of some of these demonstrations has resulted in widespread farming of prawns at different states in the country. CMFRI established the field laboratory at Narakkal, Cochin in 1974 under the Scheme, Culture and propagation of marine prawns and as a result of the investigations carried out at this centre, commercial prawns such as *Fenneropenaeus indicus, Penaeus monodon, Metapenaeus monoceros, M. dobsoni, M. affinis and Parapenaeopsis stylifera* spawned in the laboratory and their larvae were reared through different stages up to stocking size under controlled conditions. The Seed production of prawns by induced maturation through eyestalk ablation by CMFRI has made revolutionary change in the hatchery technology for prawns. This has resulted in widespread establishment of prawn hatcheries in the country with further innovations and modifications of the technology by hatchery operators and entrepreneurs. Seed production of marine blue swimmer crab *Portunus pelagicus* was developed by CMFRI and farming in ponds was also initiated. Among crustaceans, shrimp has been produced in coastal ponds in the country and about 300,000 tonnes of American white shrimp *Litopenaeus vannamei* is produced in the country outpacing the tiger shrimp *Penaeus monodon*. However, the two promising marine crustacean species are the blue swimmer crab *Portunus pelagicus* and the sand lobster *Thenus orientalis*. Though seed productions of these species have been developed by CMFRI, commercial level seed production technology for both the species are yet to be achieved.

Culture of seaweeds was initiated by CMFRI during late 1970s and was mainly carried out at Mandapam and Tuticorin, along the southeast coast of India. Though CMFRI is in a lower profile now in seaweed culture, the majority commercial farms of *Kappaphycus alavarezii* are located along these coasts in the country.

The Institute was also successful in culture of other marine organisms such as sponges, holothurians and marine turtles. Among the echinoderms occurring in India, holothurians belonging to the families Holothuridae and Stichopodidae are commercially important. *Holothuria scabra* were widely fished, processed and exported as *Beche-de-mer* till late 1990s and of late it is banned due to over exploitation. CMFRI found the species to be suitable for conservation mariculture and has successfully developed the seed production technology during 1990s.

For production of live feed for molluscan and prawn larvae in the hatchery CMFRI has isolated and maintain the stock and mass culture of phytoplankters such as *Tetraselmis gracilis*, *Chlorella marina*, *Isochrysis galbana, Chaetoceros calcitrans, Skeletonema coastatam etc*. Mass culture of rotifer *Brachionus plicatilis* and *B. rotundiformis* are also carried out in the institute. Other zooplankters, calanoid, cyclopoid and harpacticoid copepods are also cultured in the hatcheries of the institute at different locations in the country.

Marine finfish mariculture was initiated of recent, since it was felt that fish seed production also is essential for the country to meet the ever increasing demand for fish. The concerted efforts of more than a decade or so, CMFRI could achieve the seed production of cobia *Rachycentron canadum* and silver pompano *Trachinotus blochii* during 2009-10.

With global expansion of marine ornamental fish industry about 20 to 25 million marine ornamental fishes are traded annually. Nearly 98% of the marine ornamental species marketed are wild, collected mainly from coral reefs of tropical developing countries. This has been demonstrated as a viable enterprise in India threatening the long term sustainability of the trade due mainly to indiscriminate exploitation of coral reef areas, leading to degradation of the reef habitat and over exploitation of desired species. In this context CMFRI has been focusing on this aspect for the past few years and a variety of marine ornamental fishes have been bred by the institute. Techniques for broodstock development, breeding and seed production of 16 species of pomacentrids were developed and standardized by CMFRI.

CMFRI has pioneered in open sea cage culture during the last decade and has standardized cage design and mooring for Indian waters. Many species of finfishes like Asian sea bass, cobia, pompano, mullets and pearl spot were successfully reared in cages in different maritime states of the country. Among shellfishes capture based aquaculture of spiny lobsters were found to be highly profitable. CMFRI has also set up a model for community development through cage culture as in the case for *Sidi* tribe in Gujarat. Cage culture developed and popularized by CMFRI was developed as a social movement and the progress made in the coastal community in different maritime states can well be taken as a model for community development through public-private-partnership (PPP) mode. At present more than 300 cages are operated along the Indian coast in PPP mode and in the coming decade, sea cage farming will be a major fish production system in the country.

In the world scenario, contribution of India in mariculture production is very negligible. However, the contribution of CMFRI towards development of mariculture technologies are significant. In India mariculture sector is looked forward as the sector for increasing seafood production in the coming years leading into a blue revolution to provide cheaper protein and healthy food to the domestic and international populations. The role of developmental agencies as partners is prerequisite and very essential for transfer of technology through massive demonstrations. The role of agencies like National Fisheries Development Board (NFDB), Hyderabad, Marine Products Export Development Authority (MPEDA), Kochi, National Bank for Agriculture and Rural Development (NABARD) *etc.* is crucial in mariculture. Subsidies have to be pursued until the industry is well established in the country. Promotion of mariculture through natural resource management has to be emphasized for years to come towards development of sustainable mariculture in India.

Breeding and seed production of marine finfish in the Asia-Pacific Region

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Aquaculture in the Asia-Pacific region is characterised by a high species diversity that reflects the biodiversity of the region. At least 130 species of marine finfish have been trialled, or are routinely produced, in hatcheries (Table 1). There are pros and cons to this high-diversity approach to aquaculture. Having a range of species available allows farmers to pick and choose from low-value species (such as milkfish *Chanos chanos*) to high-value species (such as groupers) depending on their capacity to farm (technical) and feed (economic) the selected crop. On the other hand, it also serves to dilute the research effort, with effort being expended on trialling new species rather than focussing on a few species. This is reflected in the paucity of information about most of the species farmed in the Asia-Pacific region, as discussed further below.

Table 1. Estimated number of species of marine finfish for which hatchery technology has been trialled or is regularly undertaken in the Asia-Pacific region (Data collected by N. Svennevig & M. Rimmer)

Family (-ies)	No. of species
Latidae, Percichthyidae, Haemulidae	11
Lutjanidae, Lethrinidae	11
Groupers	26
Sparidae	10
Sciaenidae	7
Carangidae	13
Others	52
Total	**130**

Note: The species count for groupers includes hybrids.

Broodstock

Factors affecting reproduction in captive tropical marine finfish are not well known. There is almost no information on their nutritional requirements, despite a widespread acceptance that good nutrition is vital to the production of high-quality eggs and larvae. Many tropical species spawn in conjunction with lunar phases, but there is little information on how environmental variables affect reproduction. In Indonesia, tiger grouper *Epinephelus fuscoguttatus* cease spawning during the colder months when temperatures drop to around 25 °C (Sugama *et al*., 2012). However, in India, tiger grouper ceased spawning when temperatures increased to around 29–30°C (Rimmer *et al*., 2013). Whether this indicates a narrow range of suitable temperatures for tiger grouper spawning has not been established.

Genetic improvement in tropical marine finfish aquaculture has so far been limited to hybridisation, mainly with groupers. Hybrid groupers may exhibit faster growth that the parents (James *et al.,* 1999) and are reported to have better disease resistance. A major focus of research on hybrid groupers has been to incorporate the genome of the rapidly-growing giant grouper *Epinephelus lanceolatus*. *E. lanceolatus* itself is difficult to breed and rear, so incorporating its genome in a hybrid typically improves growth rate. Such hybrids typically use *E. lanceolatus* sperm that has been stripped from male giant grouper and cryopreserved (Fan *et al.*, 2014).

Larval rearing

Larval rearing of tropical marine finfish species is relatively standardised. The early larval stages are fed with small rotifer *Brachionus rotundiformis* and once when the larvae have increased in size, they are fed on brine shrimp *Artemia*. During the later stages of larval rearing, the larvae may be co-fed with a compounded pellet diet, and are usually weaned completely to pellets by the time of metamorphosis (*e.g*. Sugama *et al*., 2012). Barramundi larvae can be weaned using rotifers and compounded diets only, with no use of brine shrimp (Schipp *et al*., 2007).

Marine finfish larvae are relatively sensitive to environmental and physical conditions, and optimising these would undoubtedly improve the success of larval rearing. However, the optimal conditions, as well as practical limits, have not been established for most species. Toledo *et al.* (2002) found that different levels of salinity, aeration and light intensity all affected growth and survival of early-stage in grouper *Epinephelus coioides* larvae and it is likely that other species are similarly affected by their rearing environment.

In Taiwan, 'outdoor' or extensive larval rearing methods are used for larval rearing of some marine finfish species (Liao *et al*., 2001). Similar rearing methods, based on those developed in the United States for marine finfish larval rearing, have been used in Australia to rear barramundi/Asian seabass *Lates calcarifer* (Rutledge and Rimmer, 1991) and in New Caledonia to rear snapper *Lutjanus sebae* (A. Rivaton, pers. comm.). Advantages from extensive larval rearing include faster growth and lower fingerling production cost (Liao *et al*., 2001; Rutledge and Rimmer, 1991); the main disadvantage is that this method is less consistent than traditional 'indoor' methods (Liao *et al*., 2001).

Larval feeds

Copepods have demonstrated their suitability as a food source for early stage marine finfish larvae, including the more difficult to rear species such as groupers (Liao *et al*., 2001; Toledo *et al.*, 1999). The two main reasons that copepods are desirable as live prey for early larval stages is that the nauplii are of suitable size for even small-gape larvae such as groupers to ingest, and that copepods generally have relatively high levels of the essential fatty acid DHA and high DHA:EPA ratios (Rayner *et al*., 2015; Toledo *et al*., 1999). However, the mass culture of copepods for hatchery use remains problematic. In Taiwan, outdoor copepod production ponds may be used to provide copepods to indoor larval rearing systems (Rayner *et al*., 2015). However, Su *et al*. (2008) found that copepods harvested from outdoor ponds tested positive for the nervous necrosis virus (NNV) and suggested that copepods could potentially transfer the virus to indoor rearing systems.

In Taiwan, oyster trochophores may also be used as an initial larval feed (Liao *et al*., 2001). A wide variety of feeds are used during the later stages of larval rearing and for weaning, including live prey such as mysid shrimp and minced fish (Liao *et al*., 2001; Sugama *et al*., 2012).

Some marine finfish, notably rabbitfish (Siganidae) require live prey smaller than *B. rotundiformis* during the early larval rearing stages. Recent research in Japan and Indonesia has isolated and cultured minute rotifers to evaluate their use as prey items for larval rearing (Rimmer *et al.*, 2015; Wullur *et al*., 2009). Three species belonging to the genera *Proales*, *Colurella* and *Lecane* were shown to be smaller in size than the rotifers normally used for marine finfish larval rearing (Table 2). This suggests that development of new live prey organisms could help to overcome some of the bottlenecks with difficult-to-rear marine finfish.

Larval nutrition

It has long been recognised that larval nutrition is a key component in ensuring good health and high productivity in larval rearing. Despite this, there is relatively little information on the nutritional requirements of tropical marine finfish larvae. Research on barramundi (*L. calcarifer*) demonstrated a requirement for the highly unsaturated fatty acid (HUFA) eicosapentaenoic acid (EPA, 20:5n-3) (Dhert *et al.*, 1990; Rimmer *et al*., 1994). Grouper larvae seem to have more complex fatty acid requirements: (*E. coioides*) eggs contained high levels of docosahexanoic acid (DHA, 22:6n-3), EPA and arachidonic acid (ARA, 20:4n-6), indicating the importance of these fatty acids in larval development (Alava *et al*., 2004). Wild grouper larvae had higher levels of phospholipid than neutral lipid, whereas hatchery-sourced eggs and larvae contained higher levels of neutral lipid than phospholipid (Alava *et al*., 2004), suggesting that diets high in phospholipid are essential for larval survival and normal development.

However, these are among the few detailed studies on larval nutritional requirements amongst tropical marine finfish. Given the importance of larval nutrition, further studies on a range of marine finfish species would be valuable.

Table 2. Body measurements of minute rotifers from studies in Japan and Indonesia, compared with the commonly-used rotifer *B. rotundiformis*.

Species	Body length (mm)	Body width (mm)	Reference
Proales similis	83 ± 11	40 ± 6	Wullur *et al*. 2009
B. rotundiformis	134 ± 14	102 ± 12	
Colurella cf.*adriatica*	131 ± 12	92 ±11	Rimmer *et al*. 2015
Lecane cf.*papuana*	120 ± 5	100 ± 7.2	
B. rotundiformis	172 ± 11	123 ± 8	

Disease

Viral nervous necrosis (VNN), also known as viral encephalopathy and retinopathy (VER), caused by a beta-nodavirus, is a common disease problem in marine finfish hatcheries throughout the world, including the Asia-Pacific region (Hick *et al*., 2011). In general, it appears that VNN is the major disease that affects fingerling production in tropical marine finfish hatcheries, although empirical epidemiological studies are lacking. There is still disagreement amongst fish health researchers as to whether the main mode of viral infection in hatcheries is vertical or horizontal transmission (Hick *et al*., 2011). Furthermore, there are records of barramundi with a high prevalence (94%) of nodavirus (determined by RT-PCR) but without significant clinical disease (Hick *et al*., 2011), suggesting that older fish may have greater tolerance to nodavirus infection. Further research on the biology of the nodavirus and its host fish is necessary to develop effective management strategies for VNN.

Socio-economic aspects

Hatchery production of marine finfish is an important economic activity in many areas of Asia. In northern Bali there are numerous small-scale hatcheries producing seedstock of milkfish, shrimp and grouper, and as much as 20% of the local population is estimated to have some association with these hatcheries (Heerin, 2002). These small-scale hatcheries are important sources of employment for local people, and generate income for local communities (Heerin, 2002; Siar *et al*., 2002). Capital costs are relatively low, and 7 out of 11 hatcheries evaluated by Siar *et al*. (2002) had capital payback periods of less than 1 year. This makes them relatively affordable and consequently large numbers of small hatcheries have been constructed in northern Bali (Siar et al., 2002). Hatcheries also provide income generation for local women, who are commonly employed to count and grade grouper fingerlings (Siar *et al*., 2002).

Conclusion

Despite the role of the Asia-Pacific region as a major provider of aquacultured products to the world, seedstock production technology remains technically relatively stagnant. As noted above, there is relatively little information on broodstock management and captive reproduction, environmental requirements of larvae, larval nutrition and viral disease management and prevention. This situation is due in large part to the high diversity of fish species cultured in the Asia-Pacific region. Instead of focussing on a few high-priority species, the research and development effort is diffused across many different species. This problem is compounded by the tendency for researchers and industry to focus on trialling or developing new species/hybrids that are easier to culture, grow faster, or have specific market demand. A more focussed effort on species that are likely to be the backbone of marine finfish aquaculture in the Asia-Pacific region, such as barramundi / Asian seabass and pompano, would bring widespread benefits to the industry.

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Recent advances in breeding and seed production of marine finfish

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Introduction

Mariculture produces many high value finfish, crustaceans and molluscs like oysters, mussels, clams, cockles and scallops. In 2012 mariculture has contributed around 24.7 million tonnes of food fish globally which formed about 35.7% of the aquaculture production. World aquaculture production was 90.4 million tonnes in 2012, which contributed 42.2% to the total fish production and supplied 9.4 kg of food fish per person. Molluscs dominated the global mariculture production (60.3%) followed by finfish (22.5%), crustaceans (15.9%) and others (1.3%). In recent years a rapid growth in marine finfish culture is noted which has shown an average annual growth rate of 9.3% from 1990 onwards. The major finfish groups which are maricultured include salmonids, amberjacks, sea breams, sea bass, croakers, groupers, drums, mullets, turbot, other flatfishes, snappers, cobia, pompano, cods, puffers and tunas. (FAO, 2012; 2014). The expansion of sea cage farming on a global basis can be attributed as a shot in the arm for the increased farming of marine finfish. Cage culture has made possible the large-scale production of commercial finfish in many parts of the world and can be considered as the most efficient and economical way of rising fish. The most vital prerequisite for the development of sea cage farming is the technology for breeding and seed production and the reliable supply of good quality hatchery produced seeds of suitable high value marine finfishes. The major species for which captive breeding and hatchery production methods have been established include: Atlantic salmon *Salmo salar*, yellowtail *Seriola quinqueradiata*, breams *Sparus aurata*, *Pagrus major*, *Acanthopagrus schlegeli,* European sea bass *Dicentrarchus labrax*, Asian sea bass *Lates calcarifer,* red snapper *Lutjanus argentimaculatus,* cobia *Rachycentron canadum*, turbot *Scophthalmus maximus*, halibut *Hippoglossus hippoglossus*, cod *Gadus morhua,* Japanese flounder

Paralichthys olivaceus, yellow croaker *Pseudosciaena crocea,* many species of groupers (*Epinephelus* spp.) and pompanos (*Trachinotus* spp.).

Many countries in the Asia-Pacific Region like Australia, China, Japan, Taiwan, Philippines, Indonesia, Thailand, Malaysia and Vietnam have made substantial progress in the development of commercial level seed production technologies of high value finfish for sea farming. A good deal of research and development activities is being pursued internationally in this direction and much advancement is emerging in this sector. The chief areas of research thrust include (i) reproductive biological parameters essential for broodstock development, (ii) broodstock development systems, (iii) broodstock conditioning (iv) broodstock nutrition, (v) hormonal manipulations (vi) live feed and larviculture technologies and (vii) biotechnological interventions.

(i) Reproductive parameters

Generally the broodstock of marine finfish is developed from pre adult fishes collected from the wild. Sound knowledge on the reproductive biology of candidate species is essential for broodstock development. The age and size at first maturity, fecundity, gonado-somatic index, the size of mature egg and the reproductive strategy (whether a gonochorist or hermaphrodite) are also of concern. If the concerned species is a hermaphrodite, then the type *viz.*protandrous/ protogynous, sequential/simultaneous has to be ascertained. Hermaphroditism in fishes is often misdiagnosed, leading to the need for more conclusive diagnostic criteria and clarified terminology (Mitcheson and Liu, 2008).

Knowledge on gametogenesis (spermatogenesis and oogenesis) is essential for determining the maturity stage of the gonad, which is vital for breeding a fish. Most species recruit oocytes from primary growth (PG) to secondary growth (SG) and complete the secondary growth of oocytes in less than a year. Reproductive timing strategies in marine fishes fall along a continous from semelparous total spawners to iteroparous batch spawners with extended spawning seasons and long reproductive life spans. Oocyte developmental patterns reflect these timing strategies in terms of oocyte recruitment from PG to SG and within secondary growth. At the lifetime scale, semelparous species, which participate in only one reproductive cycle and then die, recruit all of their oocytes into secondary growth. In contrast, iteroparous species, which are more common and have the potential to participate in multiple reproductive cycles, constantly maintain a reserve of PG oocytes. One of the major objectives of aquaculture industry is to produce a large number of viable eggs with high survival. Major achievements have been made in recent years in improving protocols for higher efficiency of egg production and viability of progeny. Understanding the mechanism underlying the processes of oocyte growth and development and how these processes are coordinated, is essential for perceiving the factors affecting egg quality and fertilization. Research efforts were directed to identify environmental influences on egg quality, including the difference in quality as a consequence of diet, especially lipids, protein and vitamin content, photoperiod and physiochemical properties of the water, and husbandry practices. Great advances were also made in revealing endocrine pathways regulating egg formation and functional aspects that contribute the proper development of the future embryo (Lubzens *et al*. 2010).

A recent study in the yellowtail kingfish *Seriola lalandi* showed that changes in the size distributions and proportions of oocyte stages during ovarian development indicated multiple group synchronous oocyte development and the presence of all developmental stages of oocytes in mature ovaries revealed a capacity for multiple spawning within a reproductive season. Change in developmental stages of gametes during testicular maturation and the presence of all gamete stages in partially and fully spermiated males indicated multiple group synchronous gamete development in males. Another investigation on the reproductive maturation of wild caught female and male southern bluefin tuna *Thunnus maccoyii* (SBT) under captive conditions showed that sexually mature female SBT were observed from 101 kg in body weight and 155 cm in fork length, while male SBT were sexually mature at a smaller size (51 kg body weight and 128 cm fork length). Gonadosomatic and gonad index generally increased with increasing stages of maturation for female and male SBT and the fish sourced from the wild and held in the captive environment up to 9 years can achieve sexual maturity (Erin *et al.,* 2012).

(ii) Effective broodstock development systems

The vital requirement of broodstock development of marine finfish is a facility where the biosecure stocks can be maintained and controlled spawning can be obtained year round. The principles of broodstock management are recently reviewed by Duncan *et al.* (2013). The broodstock developed in sea cages are susceptible to mortality due to the changes in the water quality of the cage site, disease problems and impact of harmful algal blooms. Recirculating Aquaculture Systems (RAS) are tank-based systems in which fish can be grown at high density under controlled conditions. RAS use land based units to pump water in a closed loop through fish rearing tanks and consist of a series of sub-systems for water treatment which include equipment for solids removal, biological filtration, heating or cooling, dissolved gas control, water sterilization and photo-thermal control. Using RAS, sustainable production of biosecure seed of high value species all through the year employing photo-thermal conditioning is possible. Successful induced as well as volitional spawning of cobia and pompano were obtained in the recirculation aquaculture system established by CMFRI at Mandapam.

(iii) Broodstock Nutrition

The nutritional quality of the broodstock diet, the feed intake rate or the feeding period can all affect spawning, egg and larval quality and viability of any species. In the case of tropical fishes, ovarian development is often asynchronous. Oocytes in all stages of development are present at the same time and sometimes independent of season. The ovarian development starts with the formation of primary oocytes. Eventhough the oocyte may increase in size several fold during primary and early secondary growth, the most conspicuous size increase occurs during the last part of secondary growth, vitellogenesis. The fatty acid composition of yolk protein precursors, vitellogenins, synthesized in the liver and secreted into the blood can be affected by long term imbalances in the broodstock diet. Diet rich in vitamins, poly-unsaturated fatty acids (n- 3 PUFA) and micro-nutrients is essential for obtaining viable eggs and larvae. Dry pellets should include n-3 PUFA, in particular EPA (20:5 μ 3) and DHA (20:6 μ 3), which cannot be synthesized by metabolism. As in higher vertebrates, vitamin E deficiency affects reproductive performance, causing immature gonads and lower hatching rate and survival of offspring. For example, elevation of dietary a-tocopherol levels has been found to reduce the percentage of abnormal eggs and increase fecundity in the gilthead seabream *Sparus aurata*. Ascorbic acid has also been shown to play an important role in salmonid reproduction, where the dietary requirement of broodstock was higher than that of juveniles. Among different feed ingredients, cuttlefish, squid and krill meals are recognized as valuable components of broodstock diets (Izquierdo *et al*., 2001).

(iv) Broodstock conditioning

A number of environmental factors have been implicated as possible cues including photoperiod, temperature, rainfall, food supplies and pheromones, responsible for reproduction in majority of fishes. Among these, photoperiod is the most critical and the principal determinant of maturation in the salmonids, bass, breams, mullet, flatfish, sciaenids and seriolids. A combined interaction of photoperiod and temperature also play a role in the gonadal maturation of many species. Photothermal conditioning has been successfully employed in controlled breeding in land based broodstock systems. In a recent study gametogenesis was monitored histologicaly in wild caught red snapper *Lutjanus campechanus* maintained in captivity under simulated natural photothermal conditions. The results indicated that captive red snappers can complete gametogenesis in photothermal controlled conditions (Bardon *et.al*., 2015). In a report on the spawning of tiger grouper *Epinephelus fuscoguttatus* and square tail coral grouper *Plectropomus areolatus* in sea cages and onshore tanks in Andaman-Nicobar Islands, India it was noted that higher water temperature exceeding the upper thermal inhibitory limit for both the grouper species inhibited spawning (Rimmer *et al*., 2013).

(v) Hormonal manipulations

The fish reproductive cycle is separated in the growth (gametogenesis) and maturation phase (oocyte maturation and spermiation), both controlled by the reproductive hormones of the brain, pituitary and gonad. Hormonal manipulations of reproductive function in cultured fishes have focused on the use of either exogenous luteinizing hormone (LH) preparations that act directly at the level of the gonad, or synthetic agonists of gonadotropin-releasing hormone (GnRHa) that act at the level of the pituitary to induce release of the endogenous LH stores, which, in turn act at the level of the gonad to induce steroidogenesis and the process of OM and spermiation. The main factors that may have significant consequences on gamete quality-mainly on eggs-and should be considered when choosing a spawning induction procedure include (a) the developmental stage of the gonads at the time the hormonal therapy is applied, (b) the type of hormonal therapy, (c) the possible stress induced by the manipulation necessary for the hormone administration and (d) in the case of artificial insemination, the latency period between hormonal stimulation and stripping for *in vitro* fertilization (Constantinos *et al*..2010).

a. Improvement of broodstock

The ability to manipulate growth rates through the introduction of additional growth hormone (GH) can be applied to develop better broodstock instead of the conventional selective breeding. Dramatic growth enhancement has been shown using the technique in salmonids (Du *et al*., 1992; Delvin *et al*., 1994).

b. Sex change

Hormonal therapies are also applied for sex reversal and improvement of broodstock. Simultaneous hermaphrodites function concurrently as both male and female and are capable of releasing viable eggs and sperms during the same spawning event. In contrast, sequential hermaphrodites function as a male in one life phase and as female in another. If the male phase develops first, with later sex change into a female, the fish is protandrous; if the female phase develops first, with later sex change into a male, the fish is protogynous. The ability to change sex is present in at least 23 teleostean families (Helfman *et al.,* 1997) including over 350 species (Munday, 2001) of which most inhabit coral reefs.

A variety of experimental techniques have been developed to induce sex change, thus enabling measurements of hormone metabolism during the sexual transition period. Either a male in protogynous species or a female in protandrous species is removed from the social unit (*i.e.* sex change by release of suppressive dominance) or multiple numbers of the initial sex are recruited together in captivity in the absence of the terminal sex (*i.e.* sex change by induction). In both the situations, at least one individual of the initial sex is expected to undergo sexual transition (Shapiro, 1984; Munoz and Warner, 2003). These methods have been applied in the broodstock development of clown fishes and damselfishes which are highly valued coral reef fishes in the ornamental fish trade. The second method of manipulation of sex change is the administration of sex steroids (*e.g.* testosterone T), derivatives thereof (*e.g.* methyl testosterone: MT) or inhibitors of steroidogenic enzymes (*e.g.* fadrozole). These technologies have been instrumental in the successful development of broodstock of many commercially important marine finfishes such as seabass and groupers.

c. Controlled Gonadal maturation

Acquisition of seed stock from the wild during the seasonal spawning period of fish is unreliable and unpredictable and hence not suitable for commercialization of aquaculture. If reproduction can be controlled, a steady supply of seed can be produced by off-season spawning. But many fishes exhibit reproductive dysfunctions when reared in captivity due to the fact that the fish in captivity do not experience the conditions of spawning grounds and as a result there is a failure in release of maturational gonadotropin and luteinising hormone (LH). In many species hormonal treatments are the only means of controlling reproduction reliably. Over the years, a variety of hormonal techniques have been used successfully.

d. Induction of spawning

Most R & D efforts on the use of hormones to control finfish reproductive cycles in aquaculture have focused on the induction of FOM, ovulation, spermiation and spawning in fish that do not complete these processes in captivity. But, hormonal manipulations have important applications in commercial aquaculture, even for fishes that undergo FOM and spermiation spontaneously in captivity.

(vi) (a) Live feeds and Larviculture

Most marine finfishes have altricial larvae and when yolk sac is exhausted, they remain in an undeveloped state. The digestive system is rudimentary, lacking a stomach and much of the protein digestion takes place in the hind-gut epithelial cells. Altricial larvae cannot digest formulated feeds and hence live feed is vital for their survival. The movement of live feed in water stimulates larval feeding responses. Live feed organisms with a thin exoskeleton and high water content may be more palatable to the larvae when compared to the formulated diets (Stottrup and McEvoy, 2003). The hatchery production of juveniles of marine finfish is achieved globally by the use of green-water technique and the live feeds rotifer and *Artemia.*

(b) Microdiets as alternative for live feeds

Marine fish larvae fed on microdiets have not yet matched the growth and survival performances demonstrated by live feeds such as rotifers and *Artemia*. But there have been substantial achievements in reducing the reliance on live feeds especially the use of *Artemia* and weaning the larvae earlier onto microdiets; microdiets still cannot completely replace live feeds for most species. The reasons for this are like; the feed particle needs to be attractive to the larvae. The micro particles should be available to the larvae at all time, while limiting fouling of the tank. After ingestion, easier to digest raw materials should be tested and adjusted to balance the amino acid requirements of specific species. This should be linked to diet manufacture methods that may increase or decrease the particle digestibility (Kolkovski, 2013).

(c) Larval feeding behaviour

Successful prey capture by the larvae is the key factor in larviculture and hence lot of advancements has been made on larval feeding behavior. It involves interaction of complex processes *viz.* searching, detection, attack, capture, ingestion, digestion and evacuation. The feeding strategy is related to the specific characteristics of each species. Availability of suitable prey is one of the most determinant biotic factors, but feeding mode and amount of food intake are also influenced by prevailing environmental conditions. Searching depends basically on swimming capacity, while detection depends largely by means of visual, chemical and mechanical stimuli. Most marine fish hatch with immature anatomical features. Olfaction allows for more remote detection of a stimulus. The olfactory organ appears early during embryonic development. The intra and extra oral taste buds develop or proliferate some days or weeks after the first feeding. Mechanical stimuli such as touching or water movements are detected by neuromasts and the lateral line system. The progressive development and completion of all these sensory organs increase the capacity for detection and recognition of potential prey. Basically fish larvae exhibit alternating periods of swimming ability and inactivity. At first feeding, even the smallest larvae have some primordial hunting habits, but the efficacy increases with development and growth, changing from passive feeding to an active prey searching capacity.

Capture success relies not only on development stage and concomitant hunting capacity but also on the availability and accessibility of prey. After mouth opening, fish larvae need to learn hunting and have to do it quickly. High prey availability and accessibility are crucial for successfully initiating feeding. Prey size and swimming ability are primary factors determining the efficacy with which the prey is caught. Mouth gape limits the dimensions of the prey that can be ingested. Searching for appropriate prey of adequate size has been a priority for rearing fish larvae. The established prey sequencing is based on rotifers of different sizes and *Artemia* nauplii and metanauplii. Overall, the current commonly used live feeds, *Brachionus* spp. and *Artemia* spp. meet well the feeding behavior of most larvae except very small larvae at mouth opening (Holt, 2011).

(d) Larval Nutrition

Essential fatty acids (EFAs) play a vital role in larval fish nutrition. They function as (i) source of metabolic energy (ii) structural components of phospholipids (PLs) of cellular membranes and (iii) precursors of bioactive molecules. On an average the requirements for n-3LCPUFAs in larvae of marine finfish are about 3% DW diet or live prey. Optimum DHA levels in larval feeds range from 0.5 to 2.5%. Reported requirements of EPA range from 0.7 to 1.6%. Dietary ARA requirements for marine larval fish range from 0.5 to 1.2%. The optimum EPA/ARA ratios range from 3.5 to 5, whereas optimum dietary DHA/EPA ratios range from 1.2 to 8 (Holt, 2011).

Factors affecting larviculture

Light is an important environmental parameter that is known to significantly affect growth, development and survival of marine fish larvae. Larval fish rely heavily on visual cues for feeding and developmental success, and hence providing proper photoperiod, light intensity and wavelength of the light given to the larvae are essential to successful production. The light requirements are species specific and lighting characteristics are unique to a fish's environmental niche for optimal growth, survival and development. Feeding success can also be affected by varying the contrast in larval rearing tanks through different tank colours or the use of algal cells or inorganic particles to change the level of turbidity. Improved larval feeding can be attributed to improved vision in turbid waters because turbidity may provide greater contrast between the prey and the ambient background. Photoperiod also plays a vital role in larval rearing. Manipulation of photoperiod can have a major impact on larval growth and survival. Many species have shown improved growth rates when exposed to longer than natural photoperiods.

During the critical period, the density of the live feed and its nutritional qualities determine the percentage of the survival of the larvae. The density of the larvae of the concerned species should also be regulated in the larviculture tanks for getting good survival. When changing from smaller size live feed to larger size, co-feeding with both sizes of live feeds is needed for a few days. Weaning to formulated feed has to be done with great care. First feeding of the day can be done with appropriate size formulated feed. Feeding with live feed can be continued till all the larvae are weaned to formulated feed. Different sizes of formulated feeds need to be used as per the mouth size of the larvae. In addition, variety of other factors such as size of the tank, water temperature, water quality, etc., affects the larval survival and growth.

(vi) Biotechnological interventions

a. Hybridization

Hybridization is often used by aquaculturists in order to take advantage of potential desirable culture traits in offspring. Attempts to produce grouper hybrids have been difficult because of reproduction failures and low larval survival. However, in the case of *Epinephelus fuscogutatus* x *Epinephelus polyphekadion* hybrids, offspring have been shown to grow faster than either of the parental species. Successful hybridization of *E. coioides* x *E. lanceolatus* was achieved for the first time using cryopreserved sperm from giant grouper. There was no difference in percent fertilization and hatch between hybrid and non-hybrid orange-spotted grouper, but percent deformity of the hybrids (47%) was higher than non-hybrid (21%). Survival (22%) of the hybrid was lower than non-hybrid (51%) at 12 days post hatching (first feeding period). However, this difference was not significant at the end of 45-day study period (Anocha *et al*., 2011).

b. Cryopreservation

Cryopreservation of fish spermatozoa is a powerful technique for preserving the germplasm and is a prerequisite for establishing gene banks and can provide a year-round supply of fish semen, which brings great convenience for breeding and genetic studies. Most studies on gamete preservation are conducted on a laboratory scale. Not much practical progress of fish spermatozoa cryopreservation in large volume cryovials for the construction of cryobanks or commercial purposes has yet been achieved. Recently a technique for cryopreserving sea perch (*Lateolabrax japonicus*, Cuvier) semen in 1.8ml cryovials was developed. The fertilization rates of frozen semen cryopreserved for 3 days or 1 year in liquid nitrogen were not significantly different from that of fresh sperm. In fertilization trials of 230-ml eggs with frozen semen cryopreserved for 3days in liquid nitrogen, 84.8% fertilization rate and 70.1% hatching rate were obtained. (Ji *et al*., 2004)

c. Gynogenesis

Gynogenesis refers to a process of uniparental inheritance whereby the resulting offspring retain only maternal DNA. It has been used to identify sex-determining mechanisms in fish and to produce all-female populations for aquaculture. A protocol for the production of gynogenetic Atlantic halibut was developed. Various milt concentrations and UV doses were tested for providing genetically inactivated, yet motile, spermatozoa for the production of gynogenetic haploids. A population of gynogenetic diploids which comprised solely of females, was produced which makes possible the commercial culture of Atlantic halibut through gynogenesis (Harald *et al.*, 2006)

d. Surrogate broodstock

Large-scale release of hatchery-produced seeds has been conducted in order to restore worldwide fishery production;however, concerns exist regarding the genetic effects of hatchery stock on wild fish populations, due to the reduced genetic variation often associated with hatchery-reared fish. Therefore, it is important that fish seeds used in stock enhancement possess sufficient genetic diversity to mitigate their genetic impact on wildfish populations. To promote genetic diversity of artificial seed, seed production should be performed using a sufficiently large broodstock. In order to circumvent the need for these investments, a means of producing gametes that possess a large amount of genetic diversity using only a small number of surrogate-broodstock through spermatogonial transplantation was experimented. It was demonstrated that donor derived type A spermatogonia (ASGs) were capable of being colonised within the gonads of the recipients and can differentiate into either functional eggs or sperm depending on the sex of the recipient. ASGs obtained from cryopreserved whole testis could be incorporated into the recipient gonads. This would allow sufficient numbers of donor testes to be collected from local wild fish and stored using liquid nitrogen without the need to rear the donor individuals in captivity. Furthermore, if ASGs are isolated from several donor individuals and mixed prior to their transplantation into a single recipient, the resulting recipient would be expected to produce gametes genetically derived from several donor individuals. These results indicated that that the method of spermatogonial transplantation for production of surrogate broodstock could serve as a novel and efficient method of producing fish seeds with increased genetic diversity for use in aquaculture and stock enhancement (Yoji *et al.,* 2007).

e. Transgenic strain

Transgenic fish strains can be established by microinjection, but this powerful method has not been developed in marine fishes due to the difficulties associated with handling their small and fragile pelagic eggs and larvae. Recently the production of a transgenic strain of Nibe croaker *Nibea mitsukurii* (Sciaenidae), amarine fish that produces small, pelagic eggs was reported (Yoji *etal.*, 2011). Transgenic technique can also be employed to improve the broodstock. An 'all fish' gene construct consisting of ocean pout antifreeze protein (AFP) promoter fused to Chinook salmon GH cDNA was injected into salmonid embryos and due to the availability of transcription factors required for its activation, enhancement of growth in adult salmon to an average size of 3-5 times the size of non-transgenic controls , with some individuals , especially during the first few months of growth, reached as much as 10-30 times the size of controls (Du *et al*., 1992, Delvin *et al*., 1994). These fish generally appeared healthy, and some produced second and third generation offspring (Saunders *et al.,* 1998). The enhanced growth phenotype was inherited along with the genotypes.

The economic advantage of this type of manipulation is obvious and in comparison with selective breeding methods takes very little time for attaining similar success (Melamed *et al*., 2002). The establishment of genetic modification methods in marine aquaculture fishes would be a powerful tool for improving their commercially valuable traits by introducing genes that control a wide range of biological phenomena.

Summary

It is quite evident that a good deal of recent research advances had led to the success in development and standardization of broodstock and seed production of high valued marine food fishes. The knowledge on the endocrine mechanisms of sex reversal has contributed much for the development sex reversal techniques for many species. The biotechnological techniques like RIA and ELISA have played key roles in understanding the role of sex hormones and to develop techniques for inducing the final maturation and spawning of many species. Larviculture of many marine food fishes and ornamental fishes have been successful mainly due to the development of green-water technique and appropriate live feed and nutritional enrichment procedures. Efficient production of microalgae by fermentation techniques, better understanding of green-water technique and mass production of resting eggs of rotifers and copepods are vital areas which can improve larviculture success. Further advances in biotechnological interventions such as the development of better quality broodstock, hybridization techniques, cryopreservation, gynogenesis, transgenic strains and surrogate broodstock through spermatogonial transplantation can lead to the commercialisation of these technologies. In conclusion it can be said the all these research advancescan pave the way for more effective and economic seed production techniques of many high value species for the sustainable expansion marine finfish seed production and farming in the near future.

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Sea cage culture of spiny lobster in Southeast Asia

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Abstract

Development of spiny lobster aquaculture is of increasing interest around the world, as demand increases and capture fisheries supply decreases. There have been two primary sectors of research and development activity supporting the development, firstly that utilizing natural settlement of lobster seed, and secondly that developing hatchery technology. Ultimately the two sectors will merge when hatchery technology is fully commercialized and price of hatchery produced seed is equivalent to that of the natural supply, but for the time being, lobster aquaculture is 100% reliant on natural seed supply. Spiny lobster farming is well developed in Vietnam and developing in Indonesia, Philippines and Malaysia. There is strong interest throughout Asia, motivated by the success of the Vietnam industry which now generates around 1,500 tonnes of annual production of premium spiny lobsters, marketed to China and with a farm-gate value of $US 150 million. The Vietnam lobster farming industry is based on a local supply of naturally settling seed that are captured primarily at the swimming puerulus stage. Between 1.5 and 3.5 million seed are caught each year, 50 to 85% of which are *Panulirus ornatus* and the balance mostly *Panulirus homarus*. The lobsters are successfully on-grown in simple sea cages, providing a lucrative return for the village-based farmers that dominate the industry. In Vietnam there are currently around 40,000 sea cages used for lobster production. In Indonesia, a significant resource of naturally settling seed has also been identified with catch from just one location in the southeast of Lombok estimated to exceed 10 million seed per year. Grow out production however is negligible due to lack of farming skills and a preference to catch and sell the seed available. The Vietnam industry may benefit from this, as the bulk of seed exported from Indonesia are destined for Vietnam. Nevertheless, opportunity exists throughout Asia, where sea cage aquaculture is suited, using the supply of seed now being traded across the region. Sea cage growout of tropical spiny lobsters represents one of the most lucrative

aquaculture enterprises in the world, founded as it is on simple technology, minimal capital, moderate operating costs, and producing a very high value product, for which demand is well beyond supply.

Introduction

Spiny lobsters are the world's most valuable crustaceans. Many countries have an interest in spiny lobster farming but production has been limitedby the supply of seed. The reason is the difficulty in the hatchery culture of spiny lobster from the eggs through a long series of larval stages (phyllosoma) to the puerulus, which may take from four months to more than one year, depending on the species. These larvae are extremely delicate with very specific environmental and nutritional requirements and the technical difficulties in nurturing and sustaining them further exacerbates the difficulty. At this time there is no commercial hatchery production of spiny lobsters (Palinuridae) anywhere in the world.

Nevertheless, there is a significant lobster aquaculture industry in Vietnam producing more than 1,500 tonnes of cage-raised lobsters annually, and a rapidly developing spiny lobster farming industry in Indonesia. The aquaculture in these countries is based on collection of naturally setting pueruli and juveniles. Beyond Vietnam, there is some farming production of spiny lobsters in the Philippines and Malaysia, and strong interest in Thailand and India.

Until a hatchery supply of seed supply can be established, the supply of naturally settling seed is very important to sustain aquaculture production. A considerable body of knowledge is now established from studies of the seed settlement in Vietnam and Indonesia, and from population genetic studies of lobsters in the Southeast Asian region. There is evidence that exploiting the supply for aquaculture purposes has negligible impact on adult populations, and may provide a long term and sustainable resource to support lobster farming.

Seed Supply

Data on lobster seed settlement has been compiled through a series of censuses performed in Vietnam and Indonesia over recent years. This involved direct surveys comprising structured interviews of the dealers, i.e. the operators who buy lobster seed from multiple fishers,and who then on-sell the seed to lobster farmers. The structured interview included examination of the dealers' logbooks.

Seven species of *Panulirus* have been recorded among the seed catch in Vietnam including two that were the most abundant and for which detailed catch data were available; *P. ornatus* and *P. homarus,* and five less common species including *P. versicolor, P. longipes, P. penicillatus, P. polyphagus and P. stimpsoni*.

The fishery for lobster seed in Vietnam to support lobster farming is now well established. Although catches vary from year to year, there is no indication that the exploitation of the resource is unsustainable. As the economics involved are very attractive to poor coastal villagers, i.e. low risk / high return, the sector is likely to be fully developed with no more capacity. Annual catch of *P. ornatus* seed appears to be steady at between 1 and 3 million pieces per year, while that for *P. homarus* is steady at between 0.5 and 1 million pieces per year.

Lobster seed are caught in seven central to south coast Provinces from Da Nang to BinhThuan. The catch season extends over 6 to 8 months from September/October to the following March/April.

The techniques used to catch the seed are primarily aimed at catching swimming pueruli and secondarily at catching settled juveniles. For the pueruli the methods comprise: i) set seine nets, positioned to intercept the swimming pueruli, ii) netting supported by floating frames, on which pueruli settle and iii) various habitat traps made from a variety of materials suspended in the water from floating frames. The majority of pueruli captured in 2014 were caught using the seine net method.

For the juveniles (i.e. post-puerulus stage, with pigmented body and functional mouthparts), the catching method comprises various habitat traps, designed to provide an attractive habitat for the juvenile lobsters to occupy. The three most common are: i) timber posts with small holes drilled in them, ii) coral rocks with holes drilled in them and iii) netting bundles with multiple folds, edges and crevices within which the juveniles concealthemselves.

The surveys indicated that more than 95% of seed purchased by dealers are pueruli, and the remaining 5% small (< 1g) pigmented juveniles.

The price of *P. ornatus* seed between 2005/06 and 2010/11 ranged from $USD 3.00 to $9.00 each. The price per seed has continued to increase in more recent years with increasing demand, and in 2013/14 was $USD12.00 to $14.00. The reduced catch of seed in 2006/07 and 2009/10 stimulated a higher price, and in 2007/08 a milky disease outbreak created increased risk for farmers, coinciding with a large catch that year, which prompted a collapse in price. For 2014/15 the price for seed has reduced due to increased supply from imported seed from Indonesia. Current price for *P. ornatus* is around $USD5.00 per piece.

For *P. homarus* seed the price between 2005/06 and 2010/11 ranged from $USD0.60 to $2.40 each. After the 2007/08 milky disease outbreak, the price of *P. homarus* seeds increased steadily as farmers reasoned the *P. homarus* lobsters were more robust than *P. ornatus* and less susceptible to milky disease. Although the basis for that assessment has not yet been proven, an increased number of farmers now actively seek to farm *P. homarus*, as the market in China has increasingly accepted this species as a suitable substitute for *P. ornatus*, reflecting an increasing market price for 800g + lobsters. Further, *P. homarus*is thought to grow faster than *P. ornatus*, reaching a marketable size in less time.

In Indonesia, a lobster seed fishery has developed in Lombok where census data confirmed that there are six species of lobsters represented in the seed catch comprising *Panulirus homarus, P. ornatus, P. versicolour, P. longipes, P. penicillatus and P. polyphagus*, with *P. homarus* dominating the catch and *P. ornatus* the second most abundant.

Between 2009 and 2012 the annual number of seeds was relatively stable at 600,000 per year, however, in 2013 the number of seed caught increased dramatically. This is attributed to improved fishing technique, including use of lights to attract swimming pueruli, improved deployment of the shelter materials and improved positioning of the catching frames within the bay. Increase in catch is also attributable to increased effort, with many more fishers engaged in lobster seed fishing since early 2013. The total seed catch for 2013 was in excess of 3 million pieces, and approaching 10 million in 2014.

Individual price for *P. homarus* seed in Lombok was quite stable at USD $0.21 to $0.50 from 2009 through to 2012. In 2013 the price dropped to less than $0.20 each due to increased supply, but then quickly recovered and rose steadily to more than $1.34 by mid 2014. The increase can be attributed to increased demand from farmers, including export of seed from Indonesia to Vietnam, Philippines and Malaysia. Similarly, the price for *P. ornatus* seed was quite stable from 2010 through to early 2013 at $0.40 to $0.80 each, but then trended upward, to more than $1.80 in April 2014. Although the *P. ornatus* represents a relatively small proportion of the seed caught in Indonesia, and after grow out is seldom distinguished from *P. homarus*, it fetches a small premium on *P. homarus* because it is perceived to be a more valuable species.

The preferred method of capture in Indonesia consists of habitat traps suspended from floating frames that intercept the swimming pueruli. This method is cheaper and simpler than the seine net approach primarily used in Vietnam, and generates catch rates that provide a lucrative return.

The relative price of seed in Vietnam for each species is much higher, and the price discrepancy between the two species is due to the more developed nature of the lobster farming industry there and greater demand. Nevertheless, with the increased supply of seed coming from the rapidly expanding Indonesian lobster seed fishery, price of seed has been in decline over recent months.

In early 2015, Indonesia introduced a ban on export of lobster seed which resulted in a price drop to around $0.20 to $0.50 each. Further, new resources of seed have since been identified in southern Java that appear to exceed those of Lombok. The seed available in Indonesia is likely to exceed 20 million pieces per year.

Grow-out

Spiny lobster grow-out is currently well developed in Vietnam, but quite minor in Indonesia, Philippines and Malaysia. The Vietnam industry has a history dating back to the mid 1990's, and its development serves as a guide for how equivalent industries may develop elsewhere in the Southeast Asia region. Annual production is now consistently about 1,500 t, with a value of more than USD $100 million.

Production systems in Vietnam initially comprised fixed cages with an outer frame made of salt-resistant wood, 10-15cm diameter and 4 to 5m length which were embedded every 2 metres, to create a rectangular or square shape. Each cage normally had a cover, and the cage was resting on or suspended above the sea floor. Those cages placed on the sea bed had a layer of sand across the floor, while those fixed off the bottom had a gap of about 0.5 m from the sea bed. These fixed cages were the earliest form of lobster farming systems.

Submerged cages are also commonly used, particularly for nursery culture of smaller lobsters, although in some instances for growout to market size. The framework is made of iron with a diameter of 15-16mm. The bottom shape is rectangular or square with an area normally between 1 and 16 square metres. The height is 1.0 to 1.5m, and the cage has a cover and a feeding pipe.

Floating cages are currently the most common production system for lobster grow-out in Vietnam. The cages are either square or rectangular with sides of 2.8 to 4.0 m with 4.0 x 4.0m being the most common dimensions. The frame supporting the cages are made from timber planks with length of 3.5 to 5.0m; width of 8 to 15 cm, and thickness of 6 to 10 cm. The floats supporting the frame structure are reused plastic drums of about 200 litres or smaller plastic cans of 20 litres capacity.

Production of lobsters in lined earthen shrimp pond systems as an alternative to sea-cage farming was assessed in 2011, but due to the high variability of salinity (20 to 35‰) and temperature (20 to 34°C) which caused growth inhibition and at the extremes, significant mortality, earthen ponds are considered unsuitable for lobster production.

There are several health and disease issues impacting lobster farming that have constrained production, particularly milky disease. Approximately 50% of total production was lost due to milky disease in the period 2007 to 2009 comprising US$50 million lost and more than 5,000 households affected.

The mortality of the captured lobster seed prior to stocking for growout is between 40 and 60%. This mortality can be attributed to a variety of factors including capture technique, handling, transport, and during the nursery phase to nutrition and husbandry issues. If lobster losses during the capture through nursery phase could be reduced to only 10%, Vietnam's total annual lobster production could be doubled without any increase in catch.

Vietnam lobster production is currently constrained by sub-optimal nutrition, resulting from reliance on a fresh diet of low value marine species, collectively referred to as trash fish. Trash fish as used by the lobster farmers is made up of a variety of species including molluscs (~10%), crustaceans (~17%) and fish (~73%). The molluscs comprise squid, cuttlefish and some shellfish. Crustaceans include shrimps, crabs and stomatopods. Fish include lizard fish (Siganidae), big eye fish (Nemipteridae), pony fish (Leiognathidae) and others. Although an appropriate mix of these trash fish species can provide a reasonable diet, the condition of the fish when applied to the lobster cages is often poor, and over time, this diet is deficient in essential nutrients. The FCR of trash fish ranges from 17 to 30 on a fresh weight basis. It is estimated that the excess nitrogen introduced into the sea from uneaten particles and leaching of the trash fish is between 150 and 410 g/kg lobster produced. Given average annual production of 1500 tonnes, this equates to ~225 to 615 tonnes of nitrogen released into the environment each year. It is likely that such pollution is contributing to the lobster health issues referred to above.

Further compounding the unsuitability of trash fish as lobster feed, is the increasing price of trash fish, which has quadrupled in the past 10 years, from an average of US$0.25 to more than US$1.00 per kg. A formulated manufactured diet (i.e. a pellet diet) will be necessary to provide optimal and sustained nutrition.

Lobster farming in Vietnam is also constrained by availability of suitable sea cage sites. Due to competing demands on marine areas, particularly for increasing tourism, many established lobster sea cage sites have been closed to farming, forcing farmers to relocate or stop farming.

Much of the early research on aspects of husbandry and feeds development has been performed in tanks, and growth and survival in such systems was generally good. This suggests that commercial lobster production may be possible in tanks, although the cost of this approach is likely to be relatively high. In Vietnam, there is considerable interest in assessing under-utilized shrimp/clam hatchery tank production systems, as an alternative for lobster production, which in turn may enable disease issues to be better managed.

As trash fish as the source of food would be inappropriate for tank system, where stocking density may be quite high, pellet feeds will be essential. Such a diet can provide good nutrition and minimal waste, necessarily for a land-based approach.

There is opportunity in Vietnam to increase lobster production through expansion beyond the target species *Panulirus ornatus*. Although this species is likely to remain the major cultured species in Vietnam, the availability of seed of *Panulirus homarus* presents opportunity to produce this secondary species. Although *P. homarus* fetches a lower market price, it is believed to be more disease resistant and more tolerant of environmental variation. Its growth rate is as fast if not faster than *P. ornatus*, at least to a size of 300 to 500g.

Having established a successful lobster farming industry, based on natural supply of seed, Vietnam lobster farming could expand significantly if a hatchery supply of reared pueruli could be established. At present this appears to be some years away, but if it is successful, Vietnam is in a strong position to capitalize.

Regional opportunity

Based on the success of Vietnam in establishing a viable and sustainable spiny lobster farming industry, equivalent lobster farming can easily be developed in other parts of Southeast Asia. The primary limitation is perceived to be the supply of the lobster seed. Although hatchery production technology remains elusive, an increasing supply of naturally settling seed provides a strong foundation for lobster farming to expand. Recent exploratory research in Indonesia has confirmed seed supply there to be in excess of 20 million pieces per year. Using data from Vietnam, this seed supply may be converted to 10,000 tonnes of on-grown marketable lobster.

At present there is negligible grow out of lobsters in Indonesia, with most of the seed exported or used for restocking purposes. The quantity of seed available is sufficient for a substantial grow out industry to be established in Indonesia and for export to assist other countries to establish grow out.

Any uncertainty of sustainability of capturing the naturally settling seed is answered by the evidence in both Vietnam and Indonesia, where the abundance of seed in the locations where they are captured, bears no correlation to adult abundance. The evidence strongly supports that the seed populations identified are sinks, and totally disconnected from breeding populations. This proposition is further supported by population genetics research, which shows the populations of *P. ornatus* and *P. homarus* from the region are homogeneous and of a single genetic source. Based on the work of Dao*, et al.* (2013) and (Dao*, et al.*, 2015) the seed supply deposited in Vietnam and Indonesia is likely to originate in the Philippines or elsewhere, far distant from the point of settlement. Further, the natural mortality of these very high abundance, post-larval populations is likely to exceed 99%. Their exploitation provides an immediate socio-economic benefit to the costal communities that fish them, socio-economic benefit to the communities locally and elsewhere that on-grow them, and benefits to the markets that demand them.

The lobster puerulus is a relatively robust life stage of the spiny lobster, and although small (around 20mg) and transparent, it swims vigorously using energy reserves built up during the phyllosoma stage, seeking suitable habitat on which to settle. Providing these energy reserves are not fully exhausted, and the animal is not physically damaged, the puerulus at point of capture is well suited to transport to a new destination for on-growing. Although the supply of lobster seed may be focussed on just a few locations where the sink populations occur, it is not restricted to being used at those sites. Pueruli may be easily transported to locations where sea cage growout is well suited. Using air freight, these locations can be several thousand kilometres away.

A hatchery supply of lobster seed is clearly the preferred option for the long term development of spiny lobster farming. It provides numerous benefits in regard to quality and consistency of supply. Nevertheless, with suitable technology not yet developed and commercial production likely many years away, lobster farming can be established using the natural seed settlement supply. Vietnam provides an excellent example of success in this regard, and the newly identified and highly abundant supply of seed from Indonesia forms a foundation upon which a Southeast Asian regional lobster farming industry, producing in excess of 10,000 tonnes, could be established.

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Cage culture in Indonesia

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Cage culture In Indonesia is commonly practiced in freshwater, marine or coastal waters. Freshwater fish cage culture is carried out in many areas such as in lakes, reservoirs and rivers. While marine or coastal fish cage culture is carried out in several well sheltered bays available in the country and water quality is generally good. Cage culture in freshwater can be found in almost all lakes and reservoirs in Indonesia. There are number of freshwater fish species widely cultured in cages such as carp, tilapia, catfish etc. Marine cage culture can be found throughout the coastal area including Batam, Aceh, West Sumatra, Lampung, Seribu Island, Bali, Lombok and Eastern Indonesia. Marine fish species cultured in cages are grouper, barramundi, red snapper, pompano, cobia and yellow fin tuna. Most of the cage farms are relatively medium and large scale operation (50-150 cages) and fabricated using bamboo, wood or HDPE frames of various sizes (2x2 to 6x 6 m). Octagonal and round cages of varying dimensions are also used. Most of the farms are provided with shaded space for storing feed, net, other equipment and workers accommodation with electricity and high-pressure of pump for net cleaning. Fish are reared in net cage for 4-24 months depending on the size of the species. More than 300 freshwater and marine fish hatcheries and more than sixteen commercial fish feed companies are now operating to support aquaculture in Indonesia. The government of Indonesia is targeted to increase aquaculture production from 16.9 million MT in 2015 to 31.5 million MT in 2019. However, there are several constrains to both freshwater and marine cage culture including irregular seed supply in terms of quantity and quality, and diseases particularly Streptococcus, KHV for freshwater, VNN and Megalocity virus for marine fish. Other constraint is the difficulty in accessing markets and fluctuating prices.

Introduction

The increasing world demand for fish cannot be met by capture fisheries. Aquaculture production is increasing and now a days cage culture has an important role in meeting the world's fish demand. In Indonesia capture fisheries have not increased in recent years. Aquaculture is an important task for Indonesian fisheries which contribute to national food security, income and employment generation and foreign exchange earnings. Since 2001, aquaculture development in Indonesia has been accelerated as an important sector for rural economic development.

Indonesia is an archipelago with a coastline of about 95000 km and with a vast potential for aquaculture. At the national level, the extent of areas which are potential for aquaculture is estimated as 15.59 million ha consisting 2.23 million ha of fresh water, 1.22 million ha of brackishwater and 12.14 million ha of seawater resources (Nurdjana, 2006). At present, only 20% of freshwater, 48% of brackishwater and 0.26% of marine areas have been used for aquaculture activities. Aquaculture production is mainly from inland and the cage culture for marine fishes had been initiated since 1980. Based on the necessity to increase fish production in Indonesia, the design of a cage for culture is proposed that can be developed and built in the country. Present paper reviews on aquaculture development and status of cage aquaculture in Indonesia.

Aquaculture development

The total aquaculture production was increased by 206% from 4.67 million tons in 2009 to 14.31 million tons in 2014 (DG of Aquaculture, 2015). The government has a plan to increase the production from aquaculture to become 31.5 million tons in 2019 (DG of Aquaculture 2015[a]). Aquaculture is practiced in fresh, brackish and marine waters using a variety of production facilities, improved technologies and management strategies. Freshwater aquaculture development has started during late 1970s, since then a remarkable increase in production has been obtained from freshwater aquaculture. This was a result of the introduction of new farming technology which contribute to the availability of hatchery produced seed and development of commercial feed. The most common species cultured in freshwater are carp (*Cyprinus carpio*), Tilapia (*Oreochromis niloticus*), Catfish (*Pangasius sp*), Gouramy (*Osphronemus goramy*) and walking catfish (*Clarias* sp). The rapid increase of fish production was caused by the development of cage culture in reservoirs, lakes and rivers. Almost all lakes and reservoirs in Sumatra, Jawa, Sulawesi, Kalimantan and Papua in certain sites are being used for cage culture. Main constrains are KHV and *Stretococcus algalactae.*

Main species cultured in brackishwater ponds are shrimp (*Penaeus monodon* and *Litopenaneus vannamei*), milkfish (*Chanos chanos*) and recently tilapia saline (improved strain of tilapia). In shrimp culture the production of *P monodon* sharply decreased after attack by white spot virus since 1992. In order to compensate the decline in *P.monodon* production, the government decided to introduce white shrimp (*L.vannamei*) in 1999. Government through Directorate General of Aquaculture and Research Center after doing various assessment including culture technique, breeding and diseases assessment, since 2001 the government allowed its widespread farming adoption to private farms in Jawa, Sumatra, Sulawesi, Bali, Lommbok and now it is spread all over Indonesia.

At present there are a number of marine finfish species widely cultured in net cages including mouse grouper (*Cromileptes altivelis*), tiger grouper (*Epiinephelus fuscoguttatus*), giant grouper (*E. lanceolatus*), Camouflage grouper (*E.polyphekadion*) and coral trout grouper (*Plectropomus leopardus*), Asian sea bass/barramundi (*Lates calcarifer*), red snapper (*Lutjanus sebae)* napoleon wrasse (*Cheilinus undulatus*), pompano (*Trachinotus sp.*) and milkfish (*Chanos chanos)* shellfish *(Abalone*) and seaweeds mainly *Euchema cottoni* and *Euchema spinosum* and *Gracialaria vercosa*, *G. gigas* (Sugama *et al*., 2015)

History and Status of Cage culture

Cage culture has a long history in Indonesia, it is likely that the first cage were introduced to Indonesia in late of the 1970's, these early cage were constructed of bamboo or wood, but the development of modern cage culture for food fish production started in 2006 with the advent of High Density Poly Ethylene (HDPE) cages.

Prior to initiating freshwater cage culture the water body usually first be checked to ensure that the site conditions are suitable. Potential cage culture sites include lakes, reservoirs and rivers. Most of the cage culture in Indonesia is monoculture of fish species with high stocking density, mainly fed by commercial feed. In Indonesia each District may have specific laws governing the use of public water. The laws may restrict private individuals from engaging in fish farming in public water or may require permits for use of public water to the district where public water located. All cages used in the reservoir are floating cages with frame made from bamboo or wood. The stocking density varies with the type of cage, the species farmed and the local conditions. The stocking density recommended at harvest size is 16-24 kg/m^3 and normally the culture periods between 4-8 months.

Traditional cage used for marine fish are simple and small, in general 2x2x2 to 5x5x5 m, and are mostly constructed of bamboo, wooden boards, steel pipe or other local materials (such as mangrove and coconut trees). Traditional cages are made by the farmers and therefore much cheaper than offshore and modern cages made of HDPE.

At present 3 shapes and models of modern HDPE cages are manufactured in the country. The shape of cage is square, octagonal or round/circle. Circular shape is good for fast swimming fish such tuna, and milkfish while square is good for grouper and Octagonal shape for pompano and barramundi. Sea cage culture in Indonesia is carried out in many areas as there are several well sheltered bays are available and the water quality is good for rearing of marine fish. Marine cage culture can be found throughout Indonesia and are relatively medium and large scale operations (50-150 cages). At present more than 13000 HDPE cages are installed throughout Indonesia. The value for the maximum carrying capacity is very difficult to determine as it is a faction of the incoming water quality and quantity and the physiology of the fish at that particular stages of development, which is not constant but varies with time and conditions. However, based on our experience in Gondol Mariculture Research Center maximum density for marine fish such as grouper, barramundi is in the range of 20-30 kg/m^3. Main constrains are VNN and Megalocity virus

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Cage aquaculture in inland open waters of India

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Aquaculture involves eco-friendliness and is called self-cleaning industry. Cage culture, like most other aquaculture practices has been a remarkable economic growth sector in many countries during the past decade. It is an enclosure culture (fish: fry to fingerlings/fingerlings to table size/table size to marketable size) by holding aquatic organisms within an enclosed space while maintaining a free exchange of water. Its growth is expected to increase exponentially to continue in most parts of the world as the gap between supply and demand for fish is widening.

The origin of the use of cages could be traced back to the early 1800 in Southeast Asia particularly in freshwater lakes and rivers of Kampuchea while, marine fish farming in cages was traced its beginning in Japan during 1950s. However, about 35 countries in the Europe, Asia, Africa and America and more than 70 species of freshwater fish had been experimentally grown in cages. The commercial cage culture of fish was pioneered in Norway during 1970s with the development of Salmon farming. Fish culture in cages/pens in canals has been tried in Philippines, China, Indonesia and in Egypt.

In India, cage culture was attempted during 1970 for the first time in air-breathing fishes in swamps, which are marked by low dissolved oxygen (DO) in water, and for major carps in running water in rivers Yamuna and Ganga at Allahabad, and common carp (*Cyprinus carpio*), catla (*Catla catla*), silver carp (*Hypophthalmichthis molitrix*), rohu (*Labeo rohita*), snakeheads (*Channa* spp.) and tilapia (*Oreochromis niloticus*) in a still water body in Karnataka. A few preliminary trials on cage aquaculture were attempted and recently some isolated works on cage culture for raising fingerlings as well as table fish in reservoirs *viz*., Powai (Maharashtra), Govindsagar (H.P), Halali (M.P), Tandula (Chattishgarh) and Dimbereservoir (Maharashtra) has been done. Of late, cage aquaculture experiments were conducted in Walvan reservoir, Maharashtra with the stocking of *Tor putitora* and *T. khudree* to develop fry to fingerlings. In seventies, cage culture in wetlands of Assam was practiced by Scientists of Central Inland Fisheries of India (CIFRI) which got strong foot holds in ninties.

At present in India,large number of cages has been installed in different reservoirs of number of states *viz*: Jharkhand-1200 nos, Chhattisgarh-120 nos, Madhya Pradesh-144 nos, Mizoram-72 nos, Rajasthan-48 nos, Maharashtra-168 nos, Uttar Pradesh-96 nos, Karnataka-48 nos, Telangana-48 nos, Himachal Pradesh-48 nos, Gujarat-100 nos., Odisha-144 nos, Tamil Nadu-64 nos and Nagaland-24 nos. In this context, some of the remarkable cage farmings in India are the Chandil cage culture which has been crucial to ensure meaningful rehabilitation of the displaced person for Chandil Dam on river Subarnarekhain Jharkhand and has been a leading employment model for dam-displaced communities. The cage culture initiative by Visthapit Mukti Vahini under the name of Chandil Bandh Visthapit Matsyajibi Swabalambi Sahkari Samiti (CBVMSSS) has provided much needed livelihood relief to 1,163 displaced families. CBVMSSS, which oversees 17 Fishing Co-operatives, has rised the average fish production in the reservoir from 6-7 kg/ha to 80 kg/ha this year. The cumulative value of fish produced since July 2012 was over Rs. 71 lakhs. This achievement was acknowledged by Planning Commission Members. Number of entrepreneurs like Indepesca Overseas Pvt. Ltd (IOPL), Das & Kumars, Neelkamal etc. including number of feed manufacturers are involved with this novel project across India with very modest results.

The fish cage culture taken up by Kerala University Fisheries Wing with the support of RashtriyaKrishi Vikas Yojana (RKVY) in support of DoF, Govt. Of Kerala is worth mentioning. In Tamil Nadu, Cage culture in Lower Bhavani Project canal was tried in 2000-2001 having depth of 1.1-2.6 m with flow velocity 0.52-0.72 m/sec velocity by stocking Tilapia, grass carp (*Ctenopharyngodon idella*), Silver carp for Grow-out fishes and Indian major carps (IMC) for raising stocking materials.

In India, cage culture is being practiced in standing water bodies such as ponds; strip-mine pits, and barrow pits. In addition, reservoirs, rivers and streams are fruitfully being used for cage culture. In Nalbari district of Assam, cage culture in 1m^3 bamboo made cages installed in small rivulets with moderate flow for raising grow out fishes of *Anabas testudineus* and *L. rohita* (Jayanti Rohu) was tried and with good results. The cage culture activities in reservoirs of India gained impetus with renewed interests with the active involvement of Scientists of CIFRI from 2006 onwards, initially for production of stocking materials and later for production of table fish. The technology was perfected for raising stocking materials and subsequently for table fish production which was immediately taken up under Mission Mode Project (NMPS) by DAHD & F, Govt. of India with the spread of cage culture activities in 12 states of India. The technology has gained its strong foothold with the cultivation good candidate species across India which has modest bearing on livelihoods of rural India in future.

Enclosure aquaculture in inland fisheries of India

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Introduction

Fish, being an easily accessible and affordable protein food of the poor, plays a prominent role in meeting the protein requirement in the developing world. It is predicted that fish consumption in the third world will increase by 57%, from 62.7 million t in 1997 to 98.6 million t in 2020 (Delgado *et al*.,2003). Projected requirement of fish in India by 2021 is estimated at 12.0 million t. In order to achieve this target, the sector needs to record a growth rate of about 6% per annum, a tough call, but achievable. Some key inputs for fish production such as water and land are becoming scarcer on account of conflicting demands from other sectors of development. Further, fish production from natural water bodies are subject to the negative impacts of over-fishing and habitat degradation. All these, coupled with the other environmental concerns including emerging issues posed by climate change, constitute the major constraints in meeting the future demand for fish. During the last five decades, contribution of marine fish in the total production has decreased from 71% in 1950s to 39% during 2010-11 with a corresponding increase in inland fish production. This shift in catch structure in favour of the inland segment is attributable to the growth of inland aquaculture, as opposed to the sole dependence of capture fisheries in the marine counterpart. In view of the dwindling production from natural waters, both inland and marine,any substantial increase in production has to come either from inland aquaculture or mariculture.

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

Enclosure aquaculture

Enclosure aquaculture in the context of inland fisheries in India refers to 'cage culture' and 'pen culture'. Cage is an enclosed space to rear organisms in water that maintains free exchange of water with the surrounding water body. Usually covered on all sides, fish cages can be of any shape (round, square or rectangular); made of split bamboo, nylon nets or other synthetic polymers; and positioned at the bottom, middle or surface of the water column. Pens are essentially portions of a water body cordoned off by erecting a fence like structure. Usually pens are enclosed portions of the lake margin, with fencing on three sides; the free fourth side being contiguous with the land. But, pen can also be away from the shore with fencing on all the four sides. The main difference between a pen and a cage is: pen bottom is never covered so that the soil water interface of the water body is not compromised.

Relevance of enclosure culture in inland fisheries of India

India has 3.15 million ha of reservoirs and more than 5.0 lakh ha of floodplain wetlands (*beels, jheels, mauns, pats,etc*.) spread across the numerous river basins in the country. The present fish yield from reservoirs is low, to the tune of about 82 kg/ha (Jha *et al.,* 2013), in spite of their high production potential (450 kg/ha, 250 kg/ha and 100 kg/ha in small, medium and large reservoirs, respectively). Similar has been the case with floodplain wetlands where the present yield has been estimated at 400-800 kg/ha, against the production potential of 1500-2500 kg/ha (Sugunan and Sinha, 2001). Harvesting is a major problem in most of the reservoirs and lakes in the country as most of them are either weed-choked or having obstructions in the form of boulders or tree stumps limiting operation of many a fishing gear. Presence of predators often results in high natural mortality of stocked fishes causing low productivity (Sugunan, 2000). This, coupled with poor utilization of diverse food niches available in these ecosystems in the absence of efficient fish grazers, is mainly responsible for low fish yield from these ecosystems. It is prudent, therefore, to explore appropriate management measures to augment fish yield. Enclosure culture systems have a definite role to play in augmenting fish production from inland open waters in India especially reservoirs and floodplain lakes. These can overcome many production constraints in lakes and reservoirs by maintaining a captive stock, growing it on artificial feeds, protecting it from predators and enabling harvesting at will.

It has now been established beyond doubt that a major reason for the low productivity of Indian reservoirs is poor stocking compliance. Reservoirs and lakes are managed on the principle of culture-based fisheries and therefore need to be stocked with advance fingerlings in appropriate numbers in order to get the desired production level. According to one estimate, >3000 million fingerlings of size 80-100 mm are required annually to stock reservoirs alone in India

(Jha *et al*., 2013). But,due to unavailability of advanced fingerlings, vast majority of Indian reservoirs remain understocked.Available land-based nurseries are inadequate to meet the huge demand that emanates from the culture-based fisheries of reservoir fisheries. Pens and cages erected in reservoirs can be effectively used as nurseries to raise stocking material to obviate the necessity of constructing land-based nurseries which are cost-intensive. Studies conducted across three states in India have shown that encouraging *in situ* production of fingerlings has resulted in better stocking compliance and resultant high yields (Sugunan and Katiha, 2004)

Advantages of enclosed culture systems in inland fisheries can be summarised as:

- Augmenting fish yield by optimizing the use of all available water area
- Raising fingerlings in large numbers for stocking in a cost effective way
- Optimization of trophic structure and functions to the advantage of fish production
- Effective utilization of weed-choked water bodies and those with obstructions like tree stumps and boulders, where harvesting of wild fish is difficult
- In pens, lake bottom is accessible to fish and they can consume natural food from the bottom
- Reducing pressure on land for farms and nurseries
- Scope to keep a captive stock within the open water bodies allowing rapid, sure, complete and easy harvesting
- Direct and easy observation of stock for feeding, growth and general health
- Considerable indirect employment opportunities

More than 70 species of fishes belonging to diverse families have so far been experimented for enclosure culture in more than 35 countries including inland species such as Indian and Chinese carps (*Catla catla, Labeo rohita*, *L. calbasu, Cirrrhinus mrigala, Cyprinus carpio, Hypophthalmychthys molitrix*, and *Ctenopharyngodon idella*) air breathing fishes (*Anabas testudineus*, tilapia (*Oreochromis mossambicus*), snakeheads (*Channa striatus* and *C marulius*) and freshwater prawn (*Macrobrachium rosenbergii* and *M. malcolmsonii*). Most of these species have already been tried in India on experimental basis. Recently, there is considerable interest on *Ompok* spp., *Mystus* spp., *Pangasius* spp., *Wallago attu, Notopterus chitala, Etrolpus suratensis, Lates calcarifer* and *Chanos chanos*.

Cage culture

Cage culture is an age-old practice in Southeast and South Asia including India. Various contraptions like traps and fish shelters have been in vouge, which were also used for keeping fish live for a period of time. The traditional bamboo mat screens used in coastal and estuarine areas of West Bengal and Kerala are akin to pen culture. But, these traditional practices, albeit moderately successful, have little to do with the modern cage fish farming industry. There are several types of fish rearing cages viz., cages resting on the bottom, submerged cages and cages floating on the surface. Of these, floating cages are more popular and most of the research on rearing of seed, grow-out, nutritional and stocking requirements have been conducted using them. Cage shape can be round, octagonal, square or rectangular. Ideally, cage material used for aquaculture should be inexpensive, durable and easy to handle. In most cases, they have a strong outer frame made of aluminium, galvanized iron, rigid PVC tubes or HDPP pipes (to hold cage-bag shape) and the inner wall screen is made of nylon or other synthetic webbing of various mesh sizes. Cages are freely floated in mid water with some mooring device. Empty barrels and materials such as HDPP jerry cans or air tight PVC pipes, fibre glass or styloform floats are used as buoys to keep the cages afloat. Sometimes, a bamboo framework (catwalk) is floated by empty oil barrels built around a battery of cages.

In India, cage culture trials were attempted for the first time during 1960s with air breathing fish in swamps, which are marked by low dissolved oxygen in water. This was followed by trials with major carps in rivers Yamuna and Ganga at Allahabad. Similar attempts were made with common carp, silver carp, rohu, snakeheads and tilapia in a still water body in Karnataka.

Cage culture of air-breathing fishes

The first serious attempt on cage culture of air breathing fishes was made under the aegis of All India Coordinated Project for Air Breathing Fish culture, under which a series of experiments were conducted on different species. Optimum stocking densities (fingerlings/m^2) were estimated for *Anabas testudineus, Clarias batrachus, Heteropneustes fossilis, Channa striatus, C. marulius* and *C. punctatus* at 150, 200, 200, 100, 125, and 150 respectively. Culture of *C. batrachus* and *H. fossilis*, undertaken by growing themin bamboo split woven cages in Bihar and Karnataka, Assam showed encouraging results with production levels varying from 0.3 to 1.5 kg/m^3/month (Table 1). Later, experiments on *H. fossilis* lasting 112 days were conducted to compare the growth in bamboo cages (1m x 1m x 1m) with that of net cages (2m x 1m x 1m). The former returned better production figures of 23.1 against 21.5 in net cages as the bamboo cages encouraged growth of periphyton. The survival rate was 72 to 84%. Similar experiments with *Channa striatus* and *C. marulius* resulted in net production rates ranging from 3.38 to 10.65 kg/m^2.

However, in spite of the promising results obtained under the All India Coordinated Project on Air Breathing fish culture, this research did not result in any follow-up to refine, commercialize and scale up the results.

Carps in cages

The first cage fish farming of carps was initiated in Getalsud reservoir, Ranchi, Jharkhand and Gulariya reservoir, Allahabad with Indian major carps (IMC) as candidate species during 1976-1977, but the results were not very encouraging, mainly on account of poor selection of species and non-availability of suitable fish feed. The experiment was repeated in Gobindsagar reservoir during 1983-84 with IMC, but the growth was poor and the stock developed fungal infection due to bad water quality in cages on account of accumulation of unutilized feed at the bottom of the net.

Table 1. Results of air-breathing fish culture obtained under All India Coordinated Project on Air Breathing Fishes during 1980s (Source, ICAR, 2006)

Species	Stocking density	Yield (kg/m^3/month)	Feed
C. batrachus	200	0.3	Fish meal,de-oiled silk worm pupae, chick feed, soyabean meal, groundnut oil cake, rice bran
H. fossilis	200	0.7	
C. striatus	100	1.0	
C. punctatus	150	1.3	

Most of the historic experimental cage culture in carps and prawns were conducted by Central Inland Fisheries Research Institute (CIFRI), Central Institute of Freshwater Aquaculture (CIFA) and Central Institute of Fisheries Education (CIFE) across the country. Catla, rohu, mrigal, grass carp, mahseers, and freshwater prawns have been tried across the country. Some of the results have been summarized in Table 2.

More recently, the CIFRI has made some significant progress in cage culture both for raising fingerlings for stocking the reservoirs as well as raising table size fish.

Cages for fingerlings raising in reservoirs

Based on studies conducted in Pahuj and Dahod reservoirs in Rajasthan, in collaboration with the CGIAR Challenge Program on Water and Food, CIFRI has developed a technology for raising fingerlings for stocking in reservoirs. By adopting this, advanced fingerlings of Indian major carps (*C. catla, L. rohita* &

Table 2. Summary of past carp cage culture experiments in India (Source, ICAR, 2006)

Species	Place	Stocking density	Feed	Result
Catla	CIFRI	30-38/m^3	De-oiled silk worm pupae, groundnut oilcake, rice bran	2.2 kg/m^3/month (in 6 months)
Catla	CIFRI	13/m^2	Rice bran, groundnut oilcake	772g in 6 months (1.41 kg/m^2/month
	CIFRI	49/m^2	-	544 g in 8 months (2.7kg/m^2/month)
Catla	CIFA Bangalore	-	-	213.7 kg16.03kg/m^3/year
Rohu	Medchal Lake Hyderabad	70/m^3	Crude protein @ 4%	5.0 kg/cage in 89 days
Grass carp (In circular aluminium cages)	CIFA	10/m^3	Lemna, Hydrilla	400 g gain in 3 months
Tor khudree		30/m^2		216 g (171g gain)
Mixed culture of *T. putitora and T. khudree*				
T. putitora	In Vivian Lake Maharashtra	-	-	14.6 g to 201 g in 365 days
T. khudree	In Vivian Lake Maharashtra	-	-	35.2 to 285.2 g in 371 days
M. rosen-bergii	Seasonal canal	15, 30, 45, 60/m^3	Groundnut oil cake, pila meat, tilapia flesh	70.9 g I 5 months
M. rosen-bergii	Irrigation tank in Hyderabad	40/m^2	-	FCR 2.8 to 3.2
M. idae	Seasonal canal	15, 30, 45, 60/m^3	Groundnut oil cake, pila meat, tilapia flesh	3.97 g in 1 year
M. malco-lmsonii	Seasonal canal	15, 30, 45, 60/m^3	Groundnut oil cake, pila meat, tilapia flesh	70.9 g in 5 months

C. mrigala) and exotic carps (*C. carpio* and *C. idella*) can be produced to meet the stocking requirements of reservoirs. This low cost floating cages using locally available resources has been proved to be economically, socially and environmentally sound. Artificial feeding was minimal and the feed was formulated using locally available ingredients such as rice bran and mustard oil cake blended 1:1 along with vitamins, amino acids and mineral supplements. Carp fingerlings rearing under this system is based on the principle of feeding at a low trophic level, that had minimal impact on the environment, taking advantage of their various feeding habits, maximising the stocking density, minimizing competition among species, and avoiding feed waste and the resulting pollution. This technology assures a survival rate of more than 70% (Das *et al*., 2009; Table 3) . A battery of 8 cages with cage dimension 4m x 4m x 3m can meet the fingerlings requirements of 100 ha of reservoir area.

Estimated capital investment for a battery of eight cages covering 120 m^2 with aworking volume of 320 m^3 is Rs 4,117 per crop. Recurring expenses come to Rs 18,275 per crop. This yields a production cost per crop - allowing for depreciation, interest, additional expenditures, and inflation - of Rs 28,013. The market price of 70,000 fingerlings is Rs 75,000, including transport forthe first 2 years and Rs 93,500 for the remaining 3 years. The income per crop, cultured over 3 months, is Rs 61,642. This yields a highly favourable cost-benefit ratio of 2:20, with the production cost per fingerling estimated at Rs 0.40. If the fingerling culture period is reduced to 2 months, the production cost drops to Rs 0.37, enhancing the cost-benefit ratio to 2:25 (Das *et al*., 2009)

CIFRI has also successfully attempted raising table size fish of economically important species through cage culture by installing galvanized iron (GI) cages (durability more than 25 years) in Maithon reservoir, Jharkhand from the year 2011 onwards under the NFDB sponsored project on Development and demonstration of cage culture in reservoir for production of table size fish. The success of this project led to widespread adoption of this technology across the country in a number of reservoirs belonging to more than 15 States in 'Mission Mode' through National Mission for Protein Supplement (NMPS) scheme funded by DAHD&F, Govt. of India. Recently, the technology has been adopted by the Department of Fisheries, Govt. of Himachal Pradesh, where CIFRI has been providing consultancy and technical support. Forty eight modular cages have been installed in two reservoirs (Gobindsagar and Pong) and studies are in progress. It has been estimated that at present there are more than 6000 floating cages of different dimensions in inland open water resources across the country.

Table 3. Cage culture in Pahuj Reservoir, Jhansi, and Dahod Reservoir, Bhopal

Reservoir	Grow-out period	Species	Initial length (mm)	Initial weight (g)	Final length (mm)	Final weight (g)	Recovery (%)
Pahuj	16Aug-20 Dec 08	*C.catla*	11.0-15.0	0.10-0.12	80-180	6.12-74.88	87.8
		L.rohu	10.0-14.0	0.05-0.07	79-108	4.95-13.39	82.0
Dahod	10 Aug-10 Dec 08	*C.catla*	11.0-16.0	0.10-0.12	72-108	6.06-23.50	72.3
		L.rohita	10.0-17.0	0.04-0.08	68-124	4.10-19.20	77.7
		C.mrigala	12.0-17.0	0.03-0.06	62-110	3.89-14.26	72.3

Source: Das *et al*., 2009

High value fin- and shell fish species with considerable market acceptability and consumer preference like air-breathing fishes (*Clarias batrachus, Anabas testudineus, Heteropneustes fossilis, Channa marulius, C. striatus),* freshwater prawns (*Macrobrachium rosenbergii*, *M. malcolmsonii*), sea bass (*Lates calcarifer)*, carps (*Labeo bata* and *L. rohita, Cyprinus carpio, Ctenopharyngodon idella)* and catfish *(Mystus* spp., *Pangasius sutchi)* have shown good performance in cages. These can be considered for large-scale commercial cage fish farming in Indian reservoirs, subject to the availability of quality seeds at right size and in right quantity.

CIFRI Technology for cage culture of *Pangasiaodon hypophthalmus,* Common carp, Grasscarp and *Labeo bata* is being extended to the States of Andhra Pradesh, Karnataka, Bihar, Jharkhand, Orissa, Maharashtra, Chhattisgarh, Tamil Nadu, Rajasthan, Himachal Pradesh and Uttar Pradesh under the National Mission for Protein Supplements, where CIFRI is providing the technological inputs and monitoring. This involves batteries of 6-8 cages of 6m x 4m x 4m with a stocking density of 150-250m 3 assuring a production of >15 kg/m3 (Table 4)

A private entrepreneur, Indo-Pesca pvt Ltd has initiated cage culture of *P sutchi* in Desai Reservoir Mumbai where fifty cages of 5m x 4m x 3m cages produce 6 –7 t of fish per cage per year. Details of the technology packages on cage culture released by CIFRI are given in Table 5.

Table 4. Recent cage culture trials by CIFRI in different States of India (Source: CIFRI Barrackpore)

States	Number of reservoirs	Species	Number of cages	Manage-ment mode	Expected production kg per m^3 per annum
Andhra Pradesh	03	Common carp, Grass carp	144	PPP	25-30
Bihar	02	*P. sutchi*	96	PPP	50-70
Madhya Pradesh	03	*P. sutchi*	192	PPP	50-70
Odisha	02	IMC	96	State	10-15
Chhattisgarh	02	*P. sutchi*	96	State	50-70
Jharkhand	02	*P. sutchi*	96	PPP	50-70
Gujarat	01	*P. sutchi*	200	PPP	50-70
Karnataka	01	Common carp	48	PPP	25-30
Tamil Nadu	01	*P. sutchi*	48	State	50-70
Uttar Pradesh	02	*P. sutchi* /common carp	96	State	30-50
Arunachal Pradesh	01	Common carp	48	State	25-30
Assam	01	Common carp / IMC	48	State	15-30
Maharashtra	03	*P. sutchi*	144	State/PPP/Entre-preneur	50-70
Mizoram	01	Common carp	48	State	20-25
Rajasthan	01	*P. sutchi*	48	State	50-70
Tripura	01	*P. sutchi* /IMC	48	State	50-70

Table 5. CIFRI Technology packages on cage culture (Source: CIFRI Barrackpore)

Technology packages	Species	Ratio	Stocking (Nos./m^3)	Stocking size (mm)	Production
Raising of carp fingerlings (Mono –culture)	*C. catla, L.rohita, C.mrigala, C. carpio, C. idella*		200-300	10-20	150-210 nos/m^3
Raising of carp fingerlings (poly culture)	*C. catla* *L. rohita,* *C. mrigala*	25 50 25	200-300	10-20	150-210 nos/m^3
Production of table size IM carps (Mono/poly culture)	*C. catla, L. rohita, C.mrigala, C. carpio, C. idella*	10-20	80-120	6-7 kg/m^3	
Air-breathing fish culture - Table size Production of table size Pangas	*C. batrachus, H. fossilis, A. testudineus, C. striatus, C. punctatus, Pangasius sp*		50-60 30-40	75-100 80-120	6- 7 Kg/m^3 30-40 Kg/m^3

Pen culture

Pen culture is practiced traditionally in many southeast Asian countries, but the concept is relatively new in India. CIFRI has initiated pen culture trials in the country during the 1980s. After the first breakthrough achieved in Manika ox-bow lake, Muzaffarpur, Bihar, during 1982-83, CIFRI conducted a number of trials in different floodplain wetlands of India, where IMC were the culture candidates. Production levels up to 4,000 kg/ha in a culture a period of eight months were achieved (Anon, 1984). These trials were repeated in Kanti and Muktapur ox-bow lakes of Bihar (1984-86), where higher production levels of 4,000-5,000 kg/ha were achieved (Anon, 1985-88; Jha, 1993). Later, the technology was standardized and successfully demonstrated for production of both fingerlings and table-size fish in the floodplain wetlands of West Bengal and Assam with IMC and freshwater prawn as culture candidates (Sugunan *et al.,* 2000a & b; 2003). Under the NATP mission mode project, pen culture was demonstrated in 15 villages of 4 districts in Assam. This caught the imagination of people and pen culture is now being practiced in many beels without any project support. Pen fish farming technology has since been adopted widely in Assam, Bihar and West Bengal by the respective State Departments of Fisheries, and also by the self-help groups (SHGs). Salient features of CIFRI's pen culture technology is described below:

Site selection

Pen may be of square, rectangular oval, elongated or horse-shoe shaped depending on the nature of shore, land and water depth. As pens are installed towards the marginal areas of the lake leaving aside the lake proper for culture-based fisheries, they have the advantage of not interfering with or affecting the fishery of a wetland. At the pen site, the shoreline should be shallow (1.0 to 2m depth) with a gentle gradient. For prawn culture, sandy loamy or sandy clayey bottom is more suitable than clayey soils. Low depth helps in keeping the pen area hygeinic, productive and easily manageable. However, too low a depth, say less than 1 m, can lead to thermal stress to the stocked animals during warm months. Trees overhanging the pen area are not desirable as they could obstruct light and the leaves falling from the trees could accumulate in the bottom and release CO_2 through decomposing. Turbid water is unsuitable, especially if prawn is cultured. Other important favourable factors are easy avilablility of construction materials, cheap labour and accessibility to the site. As poaching is a very disturbing social problem, prevailaing social atmosphere of the locality should be verified before the site is selected. Direct loading (self weight) and external forces like impact of drift logs, aquatic vegetation, fowling organisms, mud accumulation, wind, surface waves, turbulance, etc can destroy the pens. Pen height > 2m needs special protection measures. For better management, the covered area should vary between 0.1 and 0.2 ha.

Pen materials

The pen structure consists of stake poles (main support), framework spanning over the supports, horizontal and inclined bracings, stays and mesh linings to retain fish stock. Bamboo is the most commonly used stake poles, particularly for shallow flood plain wetlands of Assam, West Bengal and Bihar. Depending on availablity and cost effectiveness, logs, cassuarina poles, and galvanized iron pipes can be used in place of bamboo. The bamboo/casuarina poles used for making the frame should be 6" to 8" in diameter and 20 to 30 feet in length.

Split bamboo/cane mats with smooth surface and sufficient length are preferred as screen materials. Iron mesh also can be used though very costly. Considering their durability, synthetic nets are the most suitable pen screen material, if chances of damage by various biotic agents and logs could be controlled. They are popular in countries like the Philppines, Thailand and Indonesia. Coir ropes or synthetic threads are the best weaving material. The mesh size of the screen is decided on the basis of initial size of the stocking materials. If the pen screens are made of split bamboo mats, a provision of additional lining with net might become necessary to prevent unwanted entry and exit of organisms. Nylon nets are used for this purpose. The nets should be cleaned perodically for facilitating water exchange and aeration inside the pen area.

Deweeding and eradication of unwanted fauna

Some reservoirs and most of the wetlands are thickly infested with macrovegetation and unwanted fauna and these need to be cleared before stocking. Besides consuming the nutrients from the water body, excessive growth of aquatic vegetation causes serious problems like upsetting the oxygen balance, creating obstruction for light penetration, movement of stocked animals and in netting operations. The aquatic weed control can be done in four different ways viz., manual, mechanical, chemical and biological. Among these, manual method is recommended in pens as it is cheap, easy and efficient. Complete eradication of unwanted oranisms from the pen before stockings is very important. While weed fishes compete with cultured species for food, space and oxygen, predators prey upon the stocked young ones. This also helps in removing other undesirable biotic communities like molluscs and insects which could interfere with the management process and affect production. Poisoning the pen area to eradicate the unwanted biotic communities is not advisable in pen culture. Liming the pen area is necessaryas it hastens mineralization of matter and hepls in maintaining the environment hygeinic. Use of quick lime @ 400 – 500 kg/ha pen area is recommended with an initial dose of 200-300 kg /ha, followed by monthly instalment @ 50- 75 kg/ha.

Pen management

The success of pen culture is largely dependent on the productivity and ecological suitability of water. The average depth of water (min 1m) in the pen is to be maintained for better results. This depends genrally on various factors like rainfall and water abstraction from the water body for irrigation, power generation etc. Generally, pen culture period excludes the monsoon season to avoid the problems of flood. Extreme summer is equally bad for pen culture as the water level recedes drastically because of high rate of evaporation and water abstraction. During summer, the temperature inside the pen shoots up and the resultant thermal stress is detrimental to the stock of fish/prawn. A water temperature range of 30-36 °C is ideal for faster growth of the cultured animals. Other desirable parameters are dissolved oxygen 4-8 mg/l, CO_2 1-2mg/l, alkailinity 50-150 mg/l, pH 7 -8 and moderate nutrient contents N -2.0 mg/l and P- 1.5 mg/l. The pen bed should be sandy clayey. The detrital load between 50 and 70 g/m^2 and organic matter between 1- 2 % are ideal for better production. Very high oragnic content of bed soil results in anaerobic conditions at the bottom which is detrimental to the bottom dwellers especially prawns.

Species selection

Planktiphagous, detritivorous and bottom feeders are the most suitable species for pen farming. However, phytophagous species can also be introduced to keep weeds under control. In pen culture, a combination of indigenous and exotic carps with the giant freshwater prawn has been proved to be successful. However, from economic point of view, monoculture of giant freshwater prawn is more profitable. A species mix of catla, silver carp, rohu and *M. rosenbergii* can be considered. In monoculture, the prawns grow faster with higher survival rate, compared to their culture along with carps. Species ratio is fixed on the basis of available food in the environment, depth of water body, seed availabilty, etc. In exclusive carp culture, a suggested ratio of fish species is surface feeder- 35% (catla 20%, silver carp 15%), Column feeder (rohu) 20% and bottom feeder (mrigal)- 45%. The bottom slot of *C.mrigala* can be replaced with prawn *M rosenbergii* in the mixed culture.

Stocking size and density

It is generally advisable to stock larger fingerlings (100 -150mm) for better survival in carp culture. Stocking size of prawn juveniles is much smaller between 65 to 70 mm (4g). Rate of stocking is fixed on the basis of the carrying capacity of the pen. In monoculture of carp, the recommeded density ranges from 4,000 to 5,000/ha, while in mixed culture, the density of carp and prawn could be 3,000 to 4,000/ha and 1,000 to 2,000/ha respectively. In monoculture of prawns, the stocking density can go as high as 30,000 to 40,000/ha.

Supplementary feeding

Since the objective of pen farming is to utilize the natural productivity of the water body, role of supplementary feeding is marginal except when prawn is cultured, which needs highly proteinous diet for growth. The prawns are fed once @ 2-5% of their body weight during evening hours depending on the availability of natural food. Supplementary feeding can also be done with commercilly available pelletized feed or locally made mixture of animal protein with carbohydrate and fat. Cockle flesh and fish meal are well known sources of animal protein. Feeding in trays saves loss of feed and thereby reducecs the cost of production.

Stock monitoring and health care

Sampling of the stocked animals needs to be done at fornightly intervals to monitor the growth and to find out any other problems in culture. Health management in pens, especially in case of higher stocking rate is very important. The general health of the stocked animals has to be satisfactory for achieving the desired production levels. Maintenance of hygeinic conditions in pen area is not difficult in view of its small area. The diseases, albeit rarely encounterted, are caused mainly by bacteria, fungi, protozoa , helminths and crustaceans. When symptoms of any disease are noticed, necessary remedial measures (which are already available), should be adopted at the earliest.

Harvesting and production

The culture period for prawns is about 4 months.

Thus, two crops could be raised per year per pen. Harvesting or recovery of fish and prawns from pens is done by nets through repeated operations. The harvesting of prawn being a bit problematic, the noctural habits of prawns may be utilized to harvest them fully. These bottom dwellers come up for feeding at night and are highly attracted towards light. It is advisbale that netting is done in the darkness (early hours) with the help of artificial light. Prawns are difficult to net out in a single day operation. Netting has to be repeated for several days for complete harvesting. Drag nets, cast nets and traps are the usual gear used for harvesting prawns. The size of harvesting being market dependent, harvesting of fish or prawn may be done as per the market demand and acceptability for getting better price.

CIFRI experiments suggest that from carp culture 4,000 to 5,000 kg of fish can be produced from one ha pen area in a year, while in mixed culture of fish and prawn an annual yield to the tune of 2,000-2,500 kg of fish and 500 to 800 kg of prawn could be harvested from 1 ha pen area. In monoculture of prawns, an average yield of 1,300 kg/ha is possible in a culture period of four months. Results of CIFRI's pen culture in Akaipur beel West Bengal is given in Table 6 and Table 7 shows CIFRI pen culture studies in Assam

Table 6. Details of CIFRI's pen culture in Akaipur beel West Bengal (Source: Sugunan et al., 2000a)

Species	***M. rosenbergii***
Stocking density	12,000 /ha
Stocking size	75 mm
Feeding	Once @3-4% body weight/day
Feed	Pelleted feed made of prawn meal
Culture period	3 months
Harvesting size	192 mm (86g)
Gain	82 g
Survival	80%
Gross production	1374 kg
Net production	1308 kg

Enclosure Culture- Constraints, pitfalls and need for precautionary approach

Although pen culture opens up opportunities for augmenting production and other economic benefits, one should be aware of some of the potential pitfalls in the form of environmental and social problems that can crop up in future.

Environmental concerns

Unplanned growth of enclosure aquaculture can lead to disastrous environmental consequences such as eutrophication. Inappropriately intensive or poorly managed cage/pen culture may pollute the environment with organic and inorganicinputs and fish faecal waste, causing eutrophication and inorganic waste build-up. If experiences gained by some of the southeast Asian countries and the lessons learnt from the coastal aquaculture boom in the 1990s are any guide, excess feed going into the water body can result in high oragnic load and excess eutrophication leading to loss of biodiversity. A success story or two can trigger a mad rush for this activity which will be difficult to stop. Research Institutes while developing production technologies, do not pay equal attention to organic loading and possible carrying capacity of lakes. India has too many lakes and reservoirs on which millions of livelihoods depend. Unchecked growth of enclosure aquaculture can convert these water bodies into barren algal blooms. Apart from losing biodiversity, it can affect millions of people who depend on capture fisheries. It should be a mandatory responsibility of those who develop technolgies to work out and fix a limit to the number of cages/pens a water body can take.

Another environmental pitfall is the introduction of exotic species during cage and pen culture. Exotic fish that escape into natural water bodies can results in irreversible changes to the biodiversity. Some exotic species have already been used in cage farming in reservoirs.

Table 7. Pen culture experiments conducted by CIFRI in Assam

Beel	Year	Area enclosed (ha.)	Fishes stocked	Stocking density (no/ha.)	Weight gain (%)	Duration of stocking (days)	Management measures	
							Liming (kg/ha)	Feeding
Peetkati	1990-91	0.1	Catla Rohu Mrigal	2000 2000 2000	2325 1085 800	180	-	Rice bran: Mustard oil cake (1:1)
Peetkati	1991-92	0.1	Catla Rohu Mrigal P. java-nicus	7030 6160 3370 500	620 800 - 430	120	-	-
Bagheswari	1996-97	0.1	Catla Rohu Mrigal	4550 4550 3900	280 155 150	90	Liming done	Ricebran: Mustard oilcake(1:1) @5% b.wt.
Bagheswari	1997-98	0.1	Catla Rohu Mrigal	3300 3850 385	75 55 36	130 200		Ricebran: Mustard oilcake(1:1) @2% b.wt
Samaguri	1998-99	0.005	Silver carp	60000	40	100	1000	Ricebran: Mustard oilcake(1:1) @5% b.wt

Cost of production

Enclosed aquaculture, especially cage farming is a feed intensive system where lot of feed is wasted leading to bad FCR values compared to land based aquafarms. This pushes up the production cost. One of the ways to overcome this problem is value addition, but Indian major carps are not suitable for fillet making. The other way is to resort to exotic species like tilapia and pangas which should be done with care in view of the environmental consequences.

Social conflicts

Industrial level expansion of enclosure aquaculture can obstruct access to fishing grounds leading to conflicts between traditional fishers and aquaculturists, apart from possible conflict with other water use sectors such as drinking water, bathing, spiritual and aesthetic concerns. Some of the other concerns are:

- Poorly positioned cages can alter current flows, worsen sedimentation and disrupt navigation or diminish the scenic value of the water body
- Cages can be damaged by natural factors like strong winds or flooding
- Theft is problem in grow-out culture but not in culture of fingerlings

Precautionary approach

Environmental consequences of cage/pen culture being unpredictable and the available methodolgies to work out the carrying capacity being far from perfect, it is always advisable to take a precautionary approach while fixing the limits on area and production targets while adopting enclosure aquaculture technologies in Indian waters.

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Microbial diseases of Asian Seabass/ Barramundi (*Lates calcarifer*)

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Asian seabass or barramundi *Lates calcarifer* is one of the highly profitable fisheries resource across India and West Pacific. The species is sought after due to its commercial value, public demand and fast growth rate. Its natural adaptation to grow in a range of salinity has enhanced the prospects of farming this fish in ponds as well as in cages. The global annual production of Asian seabass for 2013 was estimated to be over 75000 tons (FAO, 2015). Seabass aquaculture suffers loss due to diseases of microbial origin that include viral, bacterial or parasitic pathogens. The microbial outbreaks are more commonly seen in floating cages which constitutes the major proportion of marine fish culture. These outbreaks are usually precipitated by environmental fluctuation or overstocking. Overstocking is seen in all intensive aquaculture practice especially in small farms. These factors lead to stress causing the fish to become immunocompromised and eventually enabling potent microbial pathogens to colonize and invade fish tissues. Further more, the prevalence of fish diseases increase with transport, handling or arbitrary feeding regimes. Overstocking together with overfeeding severely influence the water quality by increasing nitrogenous waste and low dissolved oxygen. These events are recognised to have direct effect on immune system failure and hence massive mortality is expected when microbial infections occur (Greenwell *et al.*, 2003). This article focuses on the description of the major disease causing agents that strike seabass farms and is based on the published reports dealing with microbial pathogens in Australia, India and Southeast Asian countries and their prevention measures.

Viral Diseases

Viruses represent the highest biological population in term of number and genetic diversity in the marine ecosystem. The patterns of viral transmission are varied and depend on farm engineering and management as well as the virus life cycle. There are many reports of viral infections when subclinical carrier fish or a viral reservoir is present in the farm. However, there is increasing evidence with examples of the infections being transferred to farmed fish from the wild. Spleen and kidney necrosis is one of these examples, where virus infects over 30 species of fish in scattered marine net cages (Suanyuk *et al.*, 2010). In case of sea bass, nodavirus is the main viral pathogen. It causes viral nervous necrosis which leads to mass mortality in seabass farms. Besides nodavirus, few reports describe exotic viruses that have the potency to invade aquaculture facilities of barramundi. One example is Bohleiridovirus, a ranavirus that normally are fatal disease to ornate burrowing frog found wild in the northern territory of Australia (Moody and Owens, 1994).

Nodavirus

Nodavirus or *Lates calcarifer encephalitis virus* (LcEV) was first reported on brain lesions associated with nodavirus infections in brain tissues of diseased barramundi in Australia (Glazebrook and Campbell 1987). This has been followed with diagnosis of nodavirus in many species in different countries (Munday*et al.*, 2002). In India, high rate of mortality due to nodavirus were reported in seabass hatcheries and cages (Azad *et.al*, 2005, Parameshwaran *et.al*, 2008, Banerjee *et al.*, 2014). Nodavirus infection can be diagnosed by several methods. The provisional detection of the viral infection is by examining brain or retina tissues under light microscope or upon virus particles visualization by electron microscope. The enzyme linked specific polyclonal antibodies have been used in ELISA for quantitative and qualitative detection of the nodavirus in fish (Munday and Nakai, 1997).

One of the important inconspicuous problem in Asian seabass industry is the scale drop syndrome (SDS). It first occurred in cages in farms in Northwest Malaysia and was later reported in marine cages in Singapore in 2002. This outbreak affects larger juveniles than the ones seen in case of nodavirus infection. The mortality rates usually exceed 40% in 100-300 grams fish. The infection is characterized by dermal necrosis combined with loss of scales. Necrosis of internal organs such as spleen, liver, gastric glands and kidney are also recorded. The etiological agent is thought to be either iridovirus or herpesvirus based on electron microscopy.

Bacterial diseases

Asian seabass is not an exception to diseases caused by bacteria that lead to serious damage to cultured fish in farms or marine cages (Loganathan *et al*., 1989). Bacterial infection control strategies are many and include farm management, vaccination, antimicrobial therapeutics, probiotics and selection of disease resistant brooders which collectively increase the production cost. Some bacterial species have been reported frequently as etiological agents of fish infections. On reviewing several reports, three microbial agents have been recorded frequently. Some of them may consist of one species like *Streptococcus iniae*, while other may belong to single genus but having several species such as those causing vibriosis.

Streptococcus iniae

Str. iniae, a gram positive bacteria has a remarkably long list of hosts including fish, and humans who were handling infected fish (Weinstein *et al*., 1997; Lau *et al*., 2003). This species gained reputation as a fish pathogen after two decades when it first attacked *Tilapia nilotica* (Perera *et al*., 1994). Barramundi in Australian sea cages was affected by an acute disease known as meningoencephalitis and the causative agent was Str. *iniae*. The clinical symptoms associated with disease include exophthalmia, opacity of the eye, imbalanced movement and anorexia; in acute cases darkening of the skin and pectoral fins petechiae are noticed. Internal signs of the disease include fluid accumulation in the peritoneal cavity, hemorrhaging of the internal organs and spleen enlargement. The bacteria has been isolated from brain and kidney of all the infected fish. (Bromage *et al*., 1999). Seabass cultured in freshwater has shown similar susceptibility pattern to *Str. iniae* upon exposure to LD50 dose (Bromage and Owens, 2002). An eight-year long environmental study has thrown light on the effect of temperature range of 25-28 °C on infection of marine barramundi by *Str. iniae*. The study suggests lowering the stocking density of fish when the water is in the critical temperature range so as to reduce the bacterial influence. Also, it appears that this infection is not affected by fluctuation in salinity and acidity. *Str.inaea* is considered a pathogen threatening the fisheries industry in many Southeast Asian countries and has been reported in outbreaks among several marine fish including Asian seabass in Thailand (Suanyuk *et al.*, 2010).

Vibriosis

Vibriosis is an acute infection characterized with hemorrhagic septicemia and dermal ulceration (Humphrey and Langdon, 1986). *V. anguillarum* is the most putative fish pathogen known to cause problems in wild and farmed fish (Colorni*et al*., 1981). It has also been isolated from *Lates calcarifer* juveniles. The infected fish suffer from loss of appetite, sluggish nature and dermal lesion. Recently *V.alginolyticus* was reported to cause symptoms resembling *V. anguillarum* in Asian seabass reared in open floating cage in India (Sharma *et al.,* 2012). Furthermore, *Pseudomonas* sp. has also been isolated from infected Asian seabass farm showing symptoms similar to that of vibriosis. Barramundi infected with *Flavobacterium johnsonae* with dermal erosion in a vibrio like manner has also been reported. The mortality rate ranged from 2-5% per day for two weeks (Carson *et al*., 1993). This gram negative bacterium has been associated with serious antibiotic resistant property due to its effective efflux pump system. Many vaccine preparations such as heat killed, formalin killed or live attenuated bacteria have been tried to protect seabass against *V. anguillarum* infection (Angelidis *et al*., 2006). DNA vaccine has been experimented using major outer membrane protein (OMP) gene of *V. anguillarum* with 46% RPS (Kumar *et al*., 2008). More recently we developed a subunit vaccine using OMPK and obtained acceptable protection for vaccinated fish in laboratory trials (Hamod *et al*., 2012).

Chlamydiales

Chlamydia is a gram negative intracellular bacterium and Chlamydia-like bacteria were found associated with subclinical infection in barramundi. This condition was recorded in more than 80 fish species of commercial importance with mortality ranging from 4%-100% (Nowak and Clark, 1999). The disease caused by this bacteria is named epitheliocystis which is evidenced by formation of cyst on the gills and skin as in barramundi (Meijer *et al*., 2006). Comprehensive work on epitheliocystis of barramundi fish has recently shown that they are prone to be infected with Novel Chlamydia-like bacteria. DNA sequence analysis placed this agent into a new species. Furthermore, the study of transmission patterns of the infection has revealed the vertical and horizontal transmission of the disease. Therefore, controlling the infection is likely to be challenge just as with nodavirus infection (Stride *et al*., 2013a, Stride *et al*., 2013b).

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Regulations for sustainable shrimp farming in India

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Introduction

Shrimp culture continues to dominate the crustacean aquaculture at global level. It has grown from 0.8 million tonnes in 1991 to 4.33 million tonnes in 2012 with the corresponding value of 5.1 billion US$ to 19.43 billion US$ during the period. Though more than 35 countries report shrimp aquaculture production, more than 90% is contributed by top ten countries. More than 20 species of shrimps are being commercially cultured in various countries but the major contribution of production is from *Litiopenaus vannamei* (70%) followed by *Penaeus monodon* (18%).

Shrimp culture development is facing several critical issues which need to be addressed by policy makers to ensure its sustainability. The major ones are

a) Production loss due to diseases
b) Potential conflicts with other users of aquatic resources especially for freshwater
c) Food safety and aquatic animal health
d) Environmental impact due to aquaculture farm waste water
e) Conversion of other land categories for aquaculture
f) Introduction of alien and/or genetically altered organisms
g) Use of fish meal and fish oil

Due to the strong global interest in shrimp farming and the issues that have arisen from its development, a Consortium Program involving the World Bank, the Network of Aquaculture Centres in Asia-Pacific (NACA), the World Wildlife Fund (WWF), and the Food and Agriculture Organization of the United Nations (FAO) was initiated in 1999 to analyze and share experiences on the environmental and social impacts, and management of sustainable shrimp farming. *International Principles for Responsible Shrimp Farming* have been synthesized from the outcome of the studies and consultations conducted by the Consortium, involving a wide range of stakeholders, from government, private and non-government organizations. The *International Principles* consider technical, environmental, social and economic issues associated with shrimp farming and provide a basis for industry and government management to improve the overall sustainability of shrimp farming at national, regional and global levels.

International Principles for Responsible shrimp farming

The main objective of these principles is to provide the basis for policy and legal frame work for the governments to address the specific needs of the each of the stakeholders. The Principles also provide the basis for development of standards and certification systems. The eight principles are – Farm siting, Farm design, water use, Broodstock and post larvae, Feed management, Health management, Food safety and social responsibility. Each Principle is with justification and implementation guidance.

Evolution of Codes of Practices and Better Management Practices

Shrimp aquaculture like any other animal husbandry practices utilizes the environmental goods and services. These interactions depend on the type of culture system used, the level of utilization of natural resources, environmental characteristics of the location of the farm, type of species cultured and the level of intensification of the culture systems. A number of codes of practices for fish culture with the major objective of environment protection were in place much before shrimp farming became popular. They are a) Irish Salmon Growers Association, 1989, b) British Columbia (BC) Salmon Farmers' Association, 1998, c) British Trout Association 1995, d) ornamental Fish Industru, UK, e) Cat Fish Farmers of America and f) Australian Aquaculture Forum.

In shrimp farming also a number of codes of practices came into operation. They are a) The Environmental Code of Conduct for Australian Prawn Farmers, b) Shrimp Farming Industry of Belize, c) The Global Aquaculture Alliance (GAA), 1997, and d) Thailand Department of Fisheries Code Of Conduct (COC). These codes of practices were voluntary and were agreed to by most of the stalkeholders involved in shrimp farming. Each of these codes listed Better Management Practices (BMPs) with main objective of Environment Protection. An obvious fault in all of the shrimp farming codes of conduct is the lack of specific instructions on how to implement the BMPs suggested in the guidelines. The documents containing the GAA codes and the Thai code indicate the need for developing operational manuals with more technical instructions for the implementation of the BMPs.

Indian Scenario

In India, shrimp farming developed at an annual growth rate of nearly 15% during 1990 to 1995. During this period the development was almost unregulated and Ministry of Agriculture, Government of India issued "Guidelines for Sustainable Development and Management of Brackishwater Aquaculture" in August 1995. These guidelines were voluntary and issued mainly to create awareness among the shrimp farmers the need for proper planning.

In 1997, the shrimp farming in India entered a regulatory regime with the establishment of Aquaculture Authority as per the instructions of Apex Court, under under Section 3(3) of the Environment (Protection) Act, 1986. The Authority was assigned all the powers necessary to protect the ecologically fragile coastal areas, sea shore, water front and other coastal areas and specially to deal with the situation created by the shrimp culture industry in the coastal States. With these powers of environment protection, the Aquaculture Authority brought out Guidelines for the following.

1) Guidelines – Adopting Improved Technology for Production and Productivity in Traditional and Improved Traditional System of Shrimp Farming. 1999.
2) Effluent treatment system in shrimp farms, 2001.

In 2005, Coastal Aquaculture Authority Act was enacted and Coastal Aquaculture Authority was established and it was given total jurisdiction of all the aquaculture activities that are being carried out within 2 km from the High Tide Line. As per Rule 3 in CAA Rules, 2005, a detailed Guidelines for regulating coastal aquaculture has been notified. These guidelines are very comprehensive dealing with all aspects of *Penaeus monodon* culture. Though most of these guidelines are advisory in nature, some of them relating to the location of the farm, buffer zones and the land use are mandatory for the registration of the farms.

Introduction of *Litopenaeus vannamei* in India

Considering the disease risks of *P. monodon* culture and the success of introduction of *L. vannamei* in other south-east Asian countries, there has been a demand for introduction of the species in India. The committee on introduction of exotic species under the Ministry of Agriculture, Department of Animal Husbandry, Dairying and Fisheries has permitted experimental introductions in 2003 with strict guidelines. The pilot-scale introductions led to a serious debate on the pros and cons of introduction with one group of stakeholders totally against the introduction and the other group demanding large scale opening up of the import of *L. vannamei* broodstock. After a series of stakeholder consultations, the Ministry instituted the Risk Analysis study on the large-scale introduction of *L. vannamei* by Central Institute of Brackishwater Aquaculture and National Bureau of Fish Genetic Resources which involved the review of pilot-scale importation and culture of *L. vannamei* by the two licensed firms, review of the status of *L. vannamei* culture in southeast Asian countries, risk analysis, status of the biosecurity in Indian shrimp farms through rapid survey and identification of low-risk scenarios.

The Risk Analysis study identified five scenarios for introduction of *L. vannamei and* the level of risk for each of the scenario.

1) Unrestricted import of SPF *L. vannamei* (high-risk),
2) Restricted imports with quarantine facilities at the importers' facility (high-risk),
3) Quarantine facilities under public sector – unrestricted culture (moderate-risk),
4) Quarantine facilities under public sector with restriction on the culture practices (low-risk) and
5) Establishment of SPF multiplication centre cum quarantine under public-private partnership with restricted permits for culture (low-risk).

Low-risk categories at 4 and 5 were recommended as suitable for Indian conditions.

Government of India accepted the Risk Analysis report and chose the importation through centralized quarantine as the mode for the introduction of *L. vannamei in* the country and specific guidelines for the quarantine, seed production and culture of *L. vannamei* was drafted by an expert committee based on the risks identified.

Guidelines for mitigating the risks of introduction of *L. vannamei*

Health Risk

The major health risk identified was the possible introduction of exotic pathogens into the country along with the imported broodstock.

The following guidelines were used to overcome the risk.

- Only SPF broodstock from approved overseas SPF *L. vannamei* suppliers will be permitted for import.
- Establishment of Aquatic quarantine facility at Chennai, the port of entry as per the legal provisions under Livestock importation Act, 1898 and Formulation of SOP and monitoring by a committee headed by CAA with members from AQ&CS, CIBA, Ministry, NFDB, MPEDA, RGCA.
- Hatcheries with strict bio-security provisions are permitted to import and produce SPF *L. vannamei* seed.

Use of non-SPF broodstock

There is a possibility of greedy hatchery operators using pond reared non-SPF broodstock , which will result in contamination with indigenous pathogens and also reduced growth due to inbreeding. To overcome this problem the following guidelines were implemented.

- Only hatcheries and farms registered with CAA will be permitted to import and culture *L. vannamei.*
- A separate permission should be obtained for the purpose from CAA
- Hatcheries can sell seed only to farmers who have been permitted
- Farmers should buy only from hatcheries permitted to rear *L. vannamei* seed
- Processors should buy *L. vannamei* only from farmers permitted to culture vannamei
- A movement document will be maintained which should contain the copies of the permission granted to the source hatchery, the farm where it was cultured and the processor who is exporting.

Ecological Risk

The major ecological risk is the escape of the exotic shrimp into the natural water and their establishment leading to competition with the indigenous shrimp population thereby affecting our biodiversity.

- No direct release of wastewater from quarantine, hatcheries and farms permitted.
- Effluent treatment system is mandatory for all the three stages and ETS to include complete cholorination and dechlorination of the wastewater to prevent the accidental escape of smaller larvae and also the pathogens.

Environmental Risk

The major environmental risk is the nutrient loading in the open waters which will affect the whole area. To prevent this the following guidelines are notified:

- Stocking density of up to 60 no/m^2 permitted
- Strict compliance to waste water standards prescribed by CAA
- Effluent Treatment System mandatory for all the farms culturing *L. vannamei* irrespective of the size of the farm and at no time water should be directly released into the open source water.
- ETS should have a minimum size of the largest pond in the farm or 10% area whichever is higher.
- Regular inspection of the farms with the collection of samples of waste water will be done by a committee constituted for the purpose by CAA with State Fisheries Departments taking active role

Conclusion

Since 2009, after the introduction of SPF *L. vannamei* in the country, the shrimp production levels have increased from 1 lakh tonnes to 4.34 lakh tonnes in 2014-15 with *L. vannamei* contributing nearly 83%. But still there are heavy losses due to shrimp diseases like WSSV, IHHNV and other emerging diseases like EHP, RMS etc., Two important aspects that require additional consideration are Biosecurity in farming areas and Assured supply of quality SPF seed. Though the regulation and guidelines stipulates it, 100% implementation could be achieved only through awareness creation among the stakeholders.

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Institutional credit support for cage aquaculture in India - Policy interventions

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Introduction

Fisheries and aquaculture are considered as the "sunrise sector" in Indian economy and it has witnessed a spectacular growth of over 1100%, from 0.75 MT to 9.57 MT, during the last six decades with annual growth rate of 4.12%. It has been recognized as a powerful income and employment generator as it stimulated the growth of a number of subsidiary industries and is an important source of protein besides being a source of foreign exchange earner. With a production of around 9.57 million tonnes during 2013-14, India accounts for about 5.6% of the global fish production. During 2013, China ranked number one with production of 44 million tonnes accounting 62% of the global fish production through aquaculture. India rank 2nd with aquaculture production of 4.55 million tonnes(FAO, 2015) accounting for 6.5% of the global food fish production through aquaculture and just one tenth of aquaculture production of China.The sector contributed Rs 96824 crore to the Gross Value Added (GVA) (at current prices) during 2013-14, which is 0.92 % of the total GVA at factor cost and 5.58% of the GVA at factor cost from agriculture, forestry and fishing. Indian marine exports accounted to about 3.7% of the Global sea food exports. During the year 2014-15, exports of marine products aggregated to 10,51,243 MT valued at Rs. 33,442 crore. During the last 25 years the marine exports achieved CGAR of 7.8% in volume and 12.4% in value terms. The share of marine exports to the total exports of the country accounted for 1.16% and to that of agricultural exports accounted for around 12%. Heavy reliance on shrimp and lack of species diversification in export is an issue faced by the industry.

[1] Views expressed are personal

The Indian fisheries sector is characterised by subsistence level fishing and farming. It has been providing **full time/part time employment to over 14.49 million people** in 2013-14. The fisheries sector has been recognised to contribute towards elimination of hunger, promote health, poverty alleviation by providing **food and Nutritional security** to the vast majority of the population. Fish contributes substantially to the domestic food security of India which has a per capita consumption of more than 7kg among the fish consuming population. Despite its high growth rate, economic, employment and export contributions, the potential of the sector is not fully exploited, while the sector also faced with issues of sustainability and needs to be diversified in terms of species and farming systems with inputs in the form of technology, policy and investment to sustain its role as leading food producing system. While attempts are being made to diversify species cultured and farming systems like cage culture, enabling policy framework to utilise public water bodies for aquaculture is lacking. Credit is one of the inputs catalysing commercial development of the sector. However, lack of proper policy/ clarity on policy issues is hindering the credit flow to the sector. An attempt is made to highlight the policy framework required for sustainable development of the sector with focus on cage culture which is emerging as a potential technology both in inland and marine waters.

Structural Changes in fish production

Globally the share of marine resources has been accounted to 65% and that of inland sector to 35% of total fish production (FAO, 2014). In India the inland sector accounted 65% while, marine sector reduced to 35% during 2013 from the dominant position of 71% in the fifties. Two main factors attributed to this structural change are the stagnation of capture fisheries and emergence of aquaculture as major production contributor. During 2013 the share of aquaculture in the inland fish production rose from 2% of inland fish production and 9% of the total fish production during 1950 has been increased to 77% and 50% respectively (FAO, 2014).

Considering the stagnation in capture fisheries coupled with increasing demand for fish by the increasing population, urbanisation, preferences and income profiles *etc*, there is need to explore technologies that meet the triple bottom line benefits i.e. economic, social and environmental considerations. Aquaculture is recognised as a fastest growing food production sector world wide which can provide livelihood in rural areas, address gender issues, and can be managed with limited negative externalities with proper regulation and management. Aquaculture in India is centred around Indian major carps in the in the freshwater sector and shrimps in the coastal brackish water areas without much diversification either in species cultured or farming systems adopted. Shrimp farming itself is witnessing a paradigm shift in terms of regulations and species cultured (with exotic SPF *vannamei* becoming the major species replacing once dominant tiger shrimp). Species like Pangasius, tilapia, sea bass, cobia, groupers, *Pompano etc*. are emerging as candidate species with the development of hatchery and farming technologies by the Research and Development agencies. On one side India is importing Pangasius fillets from Vietnam to the tune of Rs.1000 crore, farmers are facing issues in marketing of *Pangasius* as there are reports of farmers not getting remunerative price for their produce.

Further, at present aquaculture in India is mostly confined to private owned farms with very little contribution from the vast stretch of common property resources in marine and inland sectors. Technologies like cage culture are emerging as potential alternatives to enhance production from open water bodies like reservoirs, lakes, estuaries, coastal and off shore areas. For a broad based and commercial development of aquaculture there is need for enabling policy framework encompassing tenure, technology dissemination, capacity building, sustainable use and management of natural resources like soil, water and biodiversity, infrastructure support, market linkages, credit, and other risk mitigation measures.

Policy Interventions to promote cage culture Technology

The package of practices of cage culture options with types of materials used and designing of cages etc has to be documented and disseminated for wider awareness and adoption of the technology. The technology of cage fabrication, mooring, monitoring, feeding and harvesting etc have to be standardised in relation to the species and environment. The site selection requirements and mapping of suitable sites/ zones have to be identified so as to build confidence among the entrepreneurs and other stakeholders who can invest in the venture. The package of practices for cage culture in the open sea have been documented to some extent by Philipose *et al*. (2012) and Syda Rao *et al*. (2013).

The potential for cage culture in Indian reservoirs (Gunjan Karnatak and Vikash Kumar, 2014) and the package of practices for cage culture in reservoirs has been documented (Das *et al.*, 2009). However there is need to disseminate the technology and capacity building of all the stakeholders/institutions involved in production, input supplies, financial institutions, insurance companies, planning authorities etc both in private and public sectors for facilitating the adoption of the technology.

Inputs

Inputs like seed, feed and others are to be readily available in time and space so that the technology could be easily adopted by the farmers. The package of practices developed should include the details of availability of all the essential inputs required. Availability of seed of optimum size is important for development of cage culture on a commercial scale. When assured supply of seed is not ensured, extension of credit support for farming becomes riskier. Similarly cage culture being intensive type of farming, feed becomes an important component. Often cage culture involves high value carnivorous fish species which demand quality feed. Feeding with low value/trash fish is considered to be socially, environmentally and economically unsustainable (FAO, 2014) and thus call for transition from low value fish to formulated feed.

Aquatic Commons- Tenure system/leasing policy

Aquaculture development in India is mainly with the investment made in private land holdings by aquafarmers while the entire open water bodies like reservoirs, beels, estuaries and coastal and oceanic waters remain almost unutilised. In addition, irrigation canals also provide potential for cage culture. Land and water rights are generally complex and poorly defined and governed by multiple acts and managed/governed by different ministries of the central government and state governments. Even there are any lease arrangements at the local Panchayat level for the open water bodies for taking up fish culture; they are mostly informal and insecure. Lackof leasing policy is a major issue which has to be taken care by the concerned states in the country before taking up commercial cage farming both in inland, coastal, estuarine and off shore waters. With the implementation of Centrally Sponsored/Central sector schemes of Govt of India and other subsidy schemes by NFDB, cage culture in reservoirs are picking up in certain states.

Aquaculture requires a policy and legal framework that creates clear title over land and water in the form of long term lease. These lease rights are required to be freely transferable so that the lease deeds can act as collateral for availing credit facilities. The process should be based on single window clearance without much administrative hurdles. Even licensing of shrimp farms in privately owned land in coastal areas is faced with bottlenecks and delays. The challenge is much more in leasing of open water bodies in the face of competing use/ rights/ or claims. Further the leasing policies are to be framed by the respective state governments both for inland water bodies as well as coastal waters in view of the state control over the subject. The issues involved in leasing policy in case of coastal waters were reviewed for mariculture activities including cage culture (Radhakrishnan and Dineshbabu, 2012). Attracting bank credit will be a challenge as banks will find it difficult to finance commercial cage culture activities without proper leasing policy/lease right.

Extension Services

Extension services are a weak link in the development of aquaculture. There is necessity for a more specialized aquaculture extension service accessible to farmers to help them with technical issues. Since aquaculture in India has been confined to limited species as of now any species diversification on account of R&D efforts involves training and capacity building of all the stakeholders. Similarly diversification in terms of farming system from that of conventional fish ponds needs proper extension support. With the establishment of National Fisheries Development Board (NFDB), the Board may have to play umbrella role in extension and development of the sector by bringing in all the stakeholders under common platform.

Awareness and Perception

Awareness of aquaculture as a viable commercial undertaking in the public and private sector and among financial institutions improves access to land, water, and financial resources. It is pertinent to say that the entire legal issues faced by shrimp farming may be attributed to awareness and perception. Hence there is a need to create awareness and public perception about the concept of cage culture.

Investment Climate

An investment climate suitable for encouraging emerging technologies like cage culture is highly desirable. Good governance, rule of law, and a clear vision of the role of the state all contribute toward this end. A favourable investment climate requires a coherent policy framework; attention to issues of tenure; coordination among public bodies and with private stakeholders; and support for science, technology, and capacity building. Financial institutions, such as development banks, may need government assurances of support during the high-risk start-up phase. There are instances where banks have circumvented lack of such enabling policy framework. Banks have evolved mechanism to finance subsistence scale of mariculture activities in coastal waters for seaweed farming. The model was financed through Self Help Group (SHG) - Bank Linkage programme spearheaded by NABARD as a collateral substitute. Further the issue of lease and acceptability of the local communities was addressed by involving only women SHGs of fishers for taking up the activity in the local area. Training and capacity building and market tie up was also established along with credit and insurance on a contract farming model. Similar such instance of involvement of SHGs for success stories in culture of mussel, oysters etc in backwaters in Kerala are also reported (Vipinkumar *et al*., 2015). However, despite banks have come forward and extending credit support for seaweed farming, still there is lack of national consensus at policy level regarding the desirability of taking up seaweed culture. Such inconsistencies always keep the financial institutions away from the sector and fisheries sector is one such sector facing lot of in consistencies. Shrimp farming faced such issues during the nineties when banks financed shrimp farming to a larger extent. Thus while we are framing the policy for cage culture in open water bodies, a comprehensive view has to be taken from environmental, social and economic angles keeping interest of the multiple stakeholders.

Pro- Poor subsistence cage aquaculture

The technologies and policy have to be deviced to attract entrepreneurs to invest in aquaculture to meet the growing demand of the domestic and export market. The strategies adopted to promote aquaculture through market-driven commercial production should not lose track of the poverty focus. In other words, commercial aquaculture can provide leadership and build the critical volume required to raise the profile of the sector, achieve economies of scale, and create opportunities for the emergence of segmentation and service providers as in the case of poultry industry. However, public policy and support are required to ensure that the smaller producers have access to the technologies, markets, and finance for aquaculture. The policy framework will have to address issues of equity and gender considerations as well. Aquaculture can be a valuable component in a wide range of projects, whether in rural development, livelihood diversification, or land and water management. In the inland context, the open water bodies offer livelihood opportunities to the landless poor in the rural areas who can make a livelihood by taking up cage culture in reservoirs. There is scope to upscale the operations by providing other required support by organising such farmers into producer organisations to realise the economies of scale and other benefits of collectivisation. The broader objectives of rural development, livelihood and nutritional security are addressed through these efforts.

The UN Sustainable Development Goal number 14 sets a target to effectively regulate harvesting and end overfishing, illegal, unreported and unregulated fishing and destructive fishing practices and implement science-based management plans, in order to restore fish stocks in the shortest time feasible, at least to levels that can produce maximum sustainable yield as determined by their biological characteristics and to provide access for small-scale artisanal fishers to marine resources and markets. Being an open access system with common property situation, the marine capture fish production in India reaching a stagnation with almost 80% of the harvestable potential being harvested, there is only limited scope for further expansion. Most of the capture fisheries are either over exploited or fully exploited with very little scope for expansion. Considering the fact that the inshore areas are overcapitalised, providing livelihood options to the coastal communities is a challenge. Some of the fishing pressure in coastal areas could be reduced/or managed by providing fishermen with alternative livelihood options. In this context cage culture in open seas could be considered as an option for the fishermen who can be engaged in cage culture in coastal/inshore areas.

Enterprise model of cage culture with higher investment of capital and technology could be considered for open seas beyond inshore areas.

Enabling Policy Framework

Cage culture with grant assistance from Government programmes

Cage culture has been taken up on pilot scale by the state government, research institutions with funding support from government programmes like National Mission for Protein Supplements (NMPS), Rashtriya Krishi Vikas Yojana (RKVY), and National

Initiative on Climate Resilient Agriculture (NICRA). National Fisheries Development Board (NFDB) provides grant support for cage culture in reservoirs and coastal waters. This has enabled demonstration of successful cage culture both in coastal waters and reservoirs. It is a welcome move that NFDB has come out with equity/subsidy schemes for open sea cage culture. However, such subsidy schemes are not addressing the tenure issues.

Institutional Credit -Priority Sector Lending

As per Priority Sector guidelines of Reserve Bank of India (RBI), all the domestic scheduled commercial banks and Foreign banks with 20 branches and above have to lendat least 40 % of their net credit to Priority sectors. The Priority sector as per RBI comprises **(i)** Agriculture, (ii) Micro, Small and Medium Enterprises, (iii) Export Credit, (iv) Education, (v) Housing, (vi) Social Infrastructure, (vii) Renewable Energy, (viii) Others.

Focus on Agriculture and Small and Marginal farmers

Further to focus on agriculture, RBI has stipulated that 18% of the net credit disbursed by the banks have to be for **direct agriculture and allied sectors**. Within the 18% target for agriculture, a target of 8% of the net bank credit has to be for Small (landholding of more than 1 ha and upto 2 ha) and Marginal (landholding up to 1 ha) Farmers. Landless agricultural labourers, tenant farmers, oral lessees and share-croppers, whose share of landholding is within the limits are prescribed for small and marginal farmers.

Eligible activities under Agriculture

The details of eligible activities under agriculture has been broadly defined to include (i) Farm Credit (which will include short-term crop loans and medium/long-term credit to farmers) (ii) Agriculture Infrastructure and (iii) Ancillary Activities. A list of eligible activities under the three sub-categories, having relevance for fisheries sector is indicated below:

(i) Farm Credit

A. Loans to **individual farmers** [including Self Help Groups (SHGs) or Joint Liability Groups (JLGs), i.e. groups of individual farmers, provided banks maintain disaggregated data of such loans], directly engaged in Agriculture and Allied Activities. The allied activities include Fisheries activities also and include among other things

a. Crop loans for allied activities

b. Medium and Long Term loans for allied activates

c. Loans to farmers under Kisan Credit Card Scheme

B. Loans to corporate farmers, farmers' producer organizations/companies of individual farmers, partnership firms and co-operatives of farmers directly engaged in Agriculture and Allied Activities. This will include:

a. (i) Crop loans to farmers including allied activities.

b. (ii) Medium and long-term loans to farmers for agriculture and allied activities.

(ii) Agriculture Infrastructure

a. Loans for construction of storage facilities (warehouses, market yards, godowns and silos) including cold storage units/ cold storage chains designed to store agriculture produce/ products, irrespective of their location.

b. Plant tissue culture and agri-biotechnology, seed production, production of bio-pesticides, bio-fertilizer, and vermi composting.

c. For the above loans, an aggregate sanctioned limit of 100 crore per borrower from the banking system, will apply.

(iii) Ancillary Activities.

a. Loans for setting up of Agriclinics and Agribusiness Centres.

b. Loans for Food and Agro-processing up to an aggregate sanctioned limit of 100 crore per borrower from the banking system.

c. Loans to Custom Service Units managed by individuals, institutions or organizations who maintain a fleet of tractors, bulldozers, well-boring equipment, threshers, combines, etc., and to undertake farm work for farmers on contract basis.

d. Bank loans to Primary Agricultural Credit Societies (PACS), Farmers' Service Societies (FSS) and Large-sized Adivasi Multi-Purpose Societies (LAMPS) for on-lending to agriculture.

e. Loans sanctioned by banks to MFIs for on-lending to agriculture sector as per the conditions specified in paragraph IX of this circular

Potential Linked Credit Plan

NABARD has been preparing the Potential Linked Credit Plans (PLP) every year by taking district as the unit for all the districts in the country. Potential for working capital, term loan are assessed after taking into account the potential available under each sub sector, status of backward and forward linkages and other support services. The PLPs are forming the basis for arriving at the Annual Credit Plan by the banks in the district. To estimate the potential for taking up various investment activities there is a need for continuous dialogue with the state government and other research and development agencies and NABARD so that the development potential are taken into account in the credit planning process itself.

Unit Cost and Model Bankable Projects

To facilitate the flow of credit, state specific activity specific unit costs for investment activities are prepared by NABARD in association with the state government and other development agencies. To promote cage culture with credit support there is need for close coordination between the state government agencies, R&D/ development agencies and NABARD to jointly work out the unit costs of investment activities for banks to extend credit support. To address the supply side and demand side issues of credit, NABARD undertakes preparation of bankable model schemes and disseminated widely among the stakeholder. Such an attempt also takes on board all the stakeholders with common objectives and understandings and perception.

Area Development Schemes and Banking Plans

To promote cage aquaculture on a commercial scale, proper zoning and preparation of integrated coastal management plan for each of the identified zones are essential. In such zones the activity could support by the bank credit by preparation of a banking plan for the identified cluster. For successful implementation of such plan the coordination of government agencies, R&D institutions and NABARD is essential. Such coordination will ensure design of cage to meet the local requirements, species cultured, training and capacity building of the fishermen facilitate adoption of BMPs, monitoring of environmental load etc.

Innovations in Credit Outreach

NABARD has initiated many innovations for financial inclusion and credit outreach like Self Help Groups, Joint Liability Groups, Farmers' Clubs and of late Farmer Producer Organisations to take advantage of the collectivisation, economy of scale, collective marketing of produce *etc*. These innovations are already proving their utility in fisheries and aquaculture sector as well especially in judicious exploitation of common pool resources. The NABARD has sanctioned Rs. 1.85 crore as financial assistance to the Kanyakumari District Fishermen Sangam Federation (KDFSF) in Tamil Nadu. The federation, in turn, would support its members for meeting their asset purchase requirements as also the working capital. The assistance to the members of the federation would be in the form of loan. The project has been sanctioned under NABARD's Producer Organization Development Fund (PODF). Further, as a developmental measure, NABARD has also sanctioned grant support of Rs. 5.10 lakh towards purchase of IT equipment, software and training or capacity building support. The federation aimed at achieving a loan of more than Rs. 10 crore by 2016-17. The Nagapattinam District Fishermen Sangam Federation - a body of fishermen and fisherwomen availed a loan of Rs 1.00 crore and successfully repaid. Theyhave also availed second loan of Rs 1.00 crore. The federation comprised 27 groups of fishermen and fisherwomen of Nagapattinam and Karaikal districts with a membership strength ranging between 60 and 80 in each group. Based on the prompt repayment of loans by fishermen and fisherwomen, the federation has planned to float a fishermen producers company. NABARD would also extend adequate support for formation and capacity building of the company.

To provide credit support to the traditional fishermen community of Krutthivennu mandal in Krishna district, Andhra Pradesh, a banking plan was prepared by NABARD. A total of 1,335 families of traditional fishermen are benefitted under the plan implemented by the Krishna District Cooperative Central Bank Limited (KDCCL), Indian Bank and Saptagiri Grameena Bank with loan commitment of Rs 2.10 crore. Such innovations could be adopted in promoting cage culture in freshwater and marine ecosystems by collectivising the fishers into any forms discussed above.

Insurance

Insurance for fisheries sector and aquaculture are required to be revived to enable the sector develop on commercial scale. Cage culture in open seas is risky venture and adequate risk mitigation measures should be there to attract institutional credit for this activity. The package of practices, cost of fabrication of cages, operational expenses in the form of seed, feed and other inputs, culture period, expected growth and farm gate price at harvest etc are required to be taken into account to devise appropriate insurance policy, in addition to the historic data on the occurrence of various events. Development Agencies like NFDB should play an anchoring role to coordinate with technology providers like R&D institutes and with the financial institutions to arrive at the standardised package of practices, financing norms, best management practices *etc*.

Loan Guarantee Mechanism could be considered

In case of risky ventures like cage culture in open seas, coastal waters, development agencies may consider introduction of loan guarantee mechanism at least during the initial phase of technology dissemination. Such measures repose the faith of the financial institutions on the strength of the technology.

Outlook

India is considered as "sleeping giant" in terms of aquaculture production due to the fact that much of the development so far has been taken place with development of aquaculture in ponds in privately owned lands while the open water bodies in the form of coastal areas/open seas, reservoirs, irrigation canals, lakes *etc* remain outside the purview of aquaculture. Of late, cage culture has been taken up in some of the reservoirs by group of fish farmers with funding support of government agencies. The sector is often referred as "sun rise sector" in view of its potential to grow. According to an assessment by a World Bank study, India has the largest projected growth in total fish production of 60.4% during 2010-30 representing 6.8% of global production by 2030. The projected growth in aquaculture during the same period will be much higher at 121.1% with India's share reaching 9.2% from the 6.7% during 2010 (World Bank, 2013). Despite vast coastal stretch, due to lack of suitable policy framework, India is not able to harness the potential for cage culture in coastal areas. Coastal cage culture also will act as buffer to absorb the excess manpower unproductively engaged in over capitalised coastal marine fisheries sector. The fisheries sector is also faced with the challenges of climate change and is one the sectors directly impacted. The technologies and management and polices should be re-oriented to address these challenges.

Conclusion

India accounts for only about 2.4% of the world's geographical area and 4% of its water resources, but has to support about 17% of the world's human population and 15% of the livestock. This naturally exerts pressure on land and water resources and thus justifies sustainable and judicious use of these resources to meet the ever increasing demand for food and nutritional security in addition to meeting other competing demands. Proper policy frame and management measures are the needed to realise the multi sectoral potential of these resources. Fisheries and aquaculture could be effectively integrated with land and water resources. Fisheries sector is at the threshold of diversification in terms of species and farming systems and requisite policy and other inputs including credit and insurance have to be dovetailed for optimum use. Package of practices for cage culture in freshwater and coastal and oceanic waters along with suitable policy for leasing of common pool resources are the major prerequisite for attracting investment in cage culture with the provision of credit support from the banks. Considering NABARD as the apex Development Financial Institution, it is spearheading many development innovations with multiple objectives. Significant among them are collateral substitutes like SHGs, Joint Liability Groups; farmers collectives like farmers clubs and their federations and Farmer Producer Organisations. This process could circumvent the lack of leasing policy etc for extending credit on subsistence scale. However, if the activity is to be scaled up on enterprise model there is need for proper leasing policy, integrated management plan to address the social, economic and environmental issues. Considering the overcapacity in the coastal marine fisheries, marine cage culture in coastal waters could help in relocating certain fishermen in such alternate livelihood options. Enterprise model with proper scientific management could be considered for cage culture in areas oceanic waters which needs higher technology, planning, investment and management capabilities. Banks experience in financing shrimp farming in India has to be kept in the back drop while planning off shore cage culture operations.

In the inland sector the traditional fishers who lost their livelihood opportunities due to deterioration of water resources could be considered to be provided with proper rights for cage culture. To leverage credit support of the formal banking system there is need for proper coordination among the various stakeholders like R&D institutions, development institutions and financial institutions.

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Cage aquaculture in India : Legal perspectives

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Cage aquaculture is a method of fish farming that involves growing fish in cages that are suspended in a water body. There are two general types of cages that are used in cage aquaculture - floating and stationary. A floating cage is made up of a floating unit from which a single or a series of netcages are suspended. Some of them are mobile and can be easily towed away. A stationary cage, on the other hand, is tied to fixed poles at their corners.Though cage culture was in vogue in India since ancient times, it was in a primitive stage, lacking orientation. The research and development efforts of various institutions particularly the Central Marine Fisheries Research Institute (CMFRI) resulted in the formal introduction of cage culture in 2007 with the support of the Department of Animal Husbandry, Dairying and Fisheries, Ministry of Agriculture, Government of India. India has been able to reach greater heights in terms of design, mooring, combating fouling and exchange of nets and related aspects in cage culture. The cage culture technology has been tested professionally at many locations along the Indian coast. Today cage based aquaculture is getting adopted rapidly in many parts of India. India's cage aquaculture sector is poised for greater opportunities as well as challenges in the years to come. In this context it is pertinent to examine whether the current legal framework in India is capable to address the multi-dimensional issues presented by the adoption of cage aquaculture in India and what is the way forward in so far as the establishment of a legal and institutional framework which facilitates the development of responsible aquaculture in India.

An overview of legal regime relating to fisheries in India

According to the Indian constitutional scheme all lands, minerals and other things of value underlying the ocean within the territorial waters or the continental shelf or the exclusive economic zone of

India are vested in the Union All other resources of the exclusive economic zone of India are also vested in the Union by virtue of Article 297.

In 1976 the Indian Parliament enacted the Territorial Waters, Continental Shelf, Exclusive Economic Zone and Other Maritime Zones of India Act, 1976. [hereinafter referred to as the '1976 Act'] Through the enactment of the 1976 Act, India declared a 200 miles exclusive economic zone on the Indian Ocean, thereby earning the exclusive rights to exploit the living and non-living resources in this area, comprising of 2.02 million sq. kilometers. It may be noted that the 1976 Act was enacted six years prior to the adoption of the UNCLOS (which later came into force only in 1994). The demarcation of maritime boundaries under the 1976 Act is almost similar to that in the UNCLOS of 1982. As per Section 5 (4) of the1976 Act, the Union has the following rights in the exclusive economic zone (EEZ):

(a) Sovereign rights for the purpose of exploration, exploitation, conservation and management of the natural resources, both living and non-living as well as for producing energy from tides, winds and currents;

(b) exclusive rights and jurisdiction for the construction, maintenance or operation of artificial islands, off-shore terminals, installations and other structures and devices necessary for the exploration and exploitation of the resources of the zone or for the convenience of shipping or for any other purpose;

(c) Exclusive jurisdiction to authorise, regulate and control scientific research;

(d) Exclusive jurisdiction to preserve and protect the marine environment and to prevent and control marine pollution; and

(e) Such other rights as are recognised by International Law.

Section 7 (6) of the 1976 Act empowers the Central Government to declare any area of the exclusive economic zone to be a designated area. The government is also given the authority to make such provisions in the 'designated area' as it may deem necessary with respect to the following matters:

1. The exploration, exploitation and protection of the resources of such designated area; or
2. Other activities for the economic exploitation and exploration of such designated area such as the production of energy from tides,winds and currents; or
3. The safety and protection of artificial islands, off-shore terminals, installations and other structures and devices in such designated area; or
4. The protection of marine environment of such designated area; or
5. Customs and other fiscal matters in relation to such designated area.

Rule making power under the 1976 Act has been delegated to the Central Government. Section 15 (2) of the 1976 Act empowers the Central Government to make Rules with the respect to the following specific matters:

(a Regulation of the conduct of any person in the territorial waters, the contiguous zone, the continental shelf, the exclusive economic zone or any other maritime zone of India;

(b) Regulation of the exploration and exploitation, conservation and management of the resources of the continental shelf;

(c) Regulation of the exploration, exploitation, conservation and management of the resources of the exclusive economic zone;

(d) Regulation of the construction, maintenance and operation of artificial islands, off-shore terminals, installations and other structures and devices referred to in sections 6 and 7;

(e) Preservation and protection of the marine environment and prevention and control of marine pollution for the purposes of this Act;

(f) Authorization, regulation and control of the conduct of scientific research for the purposes of this Act;

(g) Fees in relation to licenses and letters of authority referred to in sub-section (4) of section 6 and sub-section (5) of section 7 or for any other purpose; or

(h) any matter incidental to any of the matters specified in clauses (a) to (g).

The Indian constitution and distribution of legislative powers relating to fisheries

As per the Indian constitutional scheme "fishing and fisheries beyond territorial waters is a Union Subject while "fisheries" is a state subject. Thus the competence to enact laws with respect to fisheries in the inland waters as well as territorial waters lies with the State Legislatures and the competence to enact laws with respect to "fishing and fisheries" in the areas beyond territorial waters lies with the Union Parliament. Several coastal states in India including Kerala came forward to enact Marine Fishing Regulation Acts in the 1980s. For example the Kerala state legislature enacted the Kerala Marine Fishing Regulation Act, 1980 to provide for the *regulation of fishing by fishing vessels in the sea*[1] along the coastline of the state. [See Preamble to Kerala Marine Fishing Regulation Act, 1980]. The said legislation is said to apply to the State of Kerala including the territorial waters along the entire coastline of the state. [See sections 1(2) and 2 (i) of the Kerala Marine Fishing Regulation Act, 1980]. An examination of the Marine Fishing Regulations Acts of various coastal states in India reveal that they are not structured in such a manner as to apply to 'aquaculture activities'.

In the exercise of the power available under Entry 21 of List II various state legislatures in India have enacted inland fisheries legislations. Many of these state laws also provide for the regulation of 'aquaculture activities'. For example the 'Kerala Inland Fisheries and Aquaculture Act, 2010' was enacted by the Kerala state legislature to provide for the sustainable development, management, conservation, propagation, protection, exploitation and utilisation of the inland fishery sector in the state and for promoting social fisheries *and to regulate and control responsible aquaculture activities*. [See preamble to Kerala Inland Fisheries and Aquaculture Act,2010]. The Act also seeks to ensure protection of livelihood and traditional rights of fishermen and also the availability of nutritious fish and food security to the people [See preamble to Kerala Inland Fisheries and Aquaculture Act, 2010]. The 2010 Act is said to apply to the State of Kerala [See section 1 (2) of the Kerala Inland Fisheries and Aquaculture Act, 2010] The definition of the term 'state' in the 2010 Act does not make any reference to 'territorial waters'. [As was done in the case of the 1980 Act]. It follows from this that the 2010 Act only applies to what is called 'inland water bodies'.The Kerala Inland Fisheries and Aquaculture Rules which was notified in the Gazette on 28 May 2013 provides a framework for the effective implementation of the 2010 Act.

The scenario in the state of Kerala

The Kerala Inland Fisheries and Aquaculture Act, 2010 as well as the Kerala Inland Fisheries and Aquaculture Rules, 2013 provide an elaborate framework as regards the regulation of 'aquaculture'. An inland water body has been defined by the 2010 Act to mean a private or public water body which is utilized or utilizable for any fishery related activity. A 'private water body' has been defined to mean 'any water body or a transformable area which is the exclusive property of any person or persons or any other person have for the time being an exclusive right of fishery whether as an owner or lessee or in any other capacity'. [Section 2 (w) of Kerala Inland Fisheries and Aquaculture Act, 2010]. The term 'public water body' has been defined by the 2010 Act to mean any water body or transformable area including estuaries or backwaters or rivers or lakes, ponds or tanks or canals including irrigation canals or reservoirs or check dams or streams vested with the Government or Local Self Government Institutions under section 218 of the Kerala Municipality Act, 1994 or under section 208 (a) of the Kerala Panchayat Raj Act, 1994 or owned by Boards or any other Government-Quasi Government Institutions or organisations'. [Section 2 (x) of Kerala Inland Fisheries and Aquaculture Act, 2010] From a plain reading of the above provisions it follows that the law makers have not intended the 2010 Act to be applicable to what is generally referred to as 'marine waters'. It is also pertinent to mention here that the Kerala state legislature has also enacted a Fish Seed Act in the year 2014 to provide for the regulation of quality in production, marketing and stocking of fish seed. This legislation has also relevance in the context of aquaculture activities in the state of Kerala.

The 2010 Act confers several powers on the state government for ensuring aquaculture related development and also for the public interest of aquaculture sector. The term 'aquaculture' has been defined by the 2010 Act to mean the process of 'growing any aquatic animals or plants by collecting and conserving them naturally or artificially in restricted circumstances in any private or public water body or in any aquatic environment and includes cage culture, pen culture, running water fish culture, ornamental fish farming, fish farming in reservoirs'. [Section 2 (b) of Kerala Inland Fisheries and Aquaculture Act, 2010]. Thus 'cage aquaculture' is very well covered by the statutory definition. Acting under section 4 of the 2010 Act the state government can declare any public water body or other suitable area as an 'aquaculture area' by publishing a notification in the official gazette. [Section 4 (1) of Kerala Inland Fisheries and Aquaculture Act, 2010] The government has the power to make rules for the utilisation, restriction, regulation and control of the fisheries related activities in the 'aquaculture areas'. [Section 4 (2) of Kerala Inland Fisheries and Aquaculture Act, 2010] It can also make rules to ensure protection of 'aquaculture areas' from being utilised for any other purpose other than that specified [Section 4 (2) of Kerala Inland Fisheries and Aquaculture Act, 2010]

The 2010 Act and the 2013 Rules generally prohibit aquaculture activities in estuaries, backwaters, lagoons and creeks. However, the said areas can be used for aquaculture if they have been notified as 'aquaculture areas' under section 4 of the 2010 Act. According to the 2010 Act a person who intends to do 'aquaculture' in inland water body has to obtain the necessary *registration or license* from the government. With a view to promote sustainable aquaculture the 2010 Act and the 2013 Rules confer several powers on the state government. Persons using inland water bodies or other aquaculture areas for aquaculture activities are prohibited from making any alterations in the ecological conditions of those areas [See clause 7 (4) of the 2013 Rules]. Use of non-certified seeds as well as seeds of prohibited species in aquaculture is strictly prohibited. [See clauses 6 and 7 of 2013 Rules]. Only seeds of those species notified by the state government can be collected from natural sources for the purpose of use in aquaculture. No

[1] Emphasis added

person is permitted to undertake aquaculture activities near ecologically important areas, mangrove areas as well as breeding ground ofvarious species of fishes [See clause 8 of 2013 Rules].

FAO CCRF and aquaculture

India is a signatory to the Food and Agricultural Organisation- Code of Conduct on Responsible Fisheries (FAO CCRF) which was unanimously adopted by the FAO Conference on 31 October 1995. Though voluntary in character the FAO CCRF is global in scope and is directed towards members and non-members of FAO, fishing entities, sub-regional, regional and global organizations, whether governmental or non-governmental, and all persons concerned with the conservation of fishery resources and management and development of fisheries such as fishers, those engaged in processing and marketing of fish and fishery products and other users of the aquatic environment in relation to fisheries [Article 1.3]. The Code provides principles and standards applicable to the conservation, management and development of all fisheries. It also covers the capture, processing and trade of fishery products, fishing operations, aquaculture, fisheries research and the integration of fisheries into coastal area management [Article 1.4.]. One of the objectives of the FAO CCRF is to serve as an instrument of reference to help States to establish or to improve the legal and institutional framework required for the exercise of responsible fisheries and in the formulation and implementation of appropriate measures [Article 2 (c)].

Article 9 of FAO CCRF which deals with 'aquaculture development' requires states to establish, maintain and develop an appropriate legal and administrative framework which facilitates the development of responsible aquaculture. [Article 9.1.1] Under the FAO CCRF the states have an obligation to ensure that the livelihoods of local communities, and their access to fishing grounds, are not negatively affected by aquaculture developments. [Article 9.1.4.] It also casts an obligation to undertake appropriate environmental assessment and monitoring with the aim of minimizing adverse ecological changes and related economic and social consequences resulting from *water extraction, land use,*[2] discharge of effluents, use of drugs and chemicals and other aquaculture activities.

THE WAY FORWARD

It is to be remembered that aquaculture was not a significant activity in India when the Constitution and the 1976 Act were adopted and the legislative regime was not drafted with aquaculture activities in mind. Cage aquaculture in India was only developed in the latter half of the first decade of 21st century. Be that as it may, it is not surprising that one does not find any reference to the said activities either in the Constitution of India, 1950 or in the 1976 Act. The Marine Fishing Regulation Acts of various states are also silent on this point. Further, there is very little case law that deals with how the existing legislative regime applies to aquaculture activities. This means that the interpretation of how current legal measures apply to aquaculture is complicated and uncertain.

At present India does not have an exclusive fisheries legislation covering the exclusive economic zone. Fishing operations in the exclusive economic zone are governed at present by the "2014 Guidelines for Fishing Operations in Indian Exclusive Economic Zone". The scheme of the said 'Guidelines' makes it clear that it is not intended to apply to 'aquaculture activities'. Though the 1976 Act confers rule making powers to the central government it is not likely to be an effective tool for regulating 'cage aquaculture activities', if any, within the exclusive economic zone. Firstly, the central government has not, till date, adopted any rules under the 1976 Act. Secondly, the power conferred by section 15 (2) (c) only relates to *regulation of the exploration, exploitation, conservation and management of the resources of the exclusive economic zone*.

The competence to enact laws with respect to 'fisheries' in territorial waters' lies with the state legislatures. As things stand at present no 'state' in India has enacted a legislation to regulate 'aquaculture activities' in territorial waters.

Since 2007, cage aquaculture has become an integral component of Indian fisheries. It is therefore necessary that clear policies and comprehensive legal regimes are developed for cage aquaculture so as to facilitate sustainable development of cage aquaculture in India. The various scenarios that need to be addressed while framing the policies and legal regime are discussed below. If a legal framework has to be developed for 'cage aquaculture' in the EEZ the same can only be adopted by the Union Parliament. As per the ordinary rules regarding distribution of legislative powers, if a legal framework has to be developed for 'cage aquaculture' in the territorial waters it can only be developed by the state legislatures. However, it is also possible for the union parliament to legislate for this area by taking the route of Article 249 or Article 253.

Who should be permitted to undertake 'cage aquaculture activities" and where can it be permitted? Who can give the necessary approvals for the same.These questions assume particular relevance depending upon whether the installation is to be made in 'inland waters', in ''territorial waters', or in the 'exclusive economic zone'. Decisions related to authorizations for interference with navigation are particularly important to the allocation of aquatic space. With respect to navigation, it is clear that a cage aquaculture site will not be approved if it is in the middle of a major navigation channel. There are, however, no clear and precise policies in place to determine when an interference with navigation is acceptable. The only provision which appears to address this scenario is section 44 B, 44 Cand 44 D of the Inland Vessels Act, 1917. According to section 44 B the competent officer may remove any timber, raft or *other thing*[3], floating or being in any part of the inland water, which in his opinion, obstructs or impedes the free navigation thereof or the lawful use of any landing place or embankment or part thereof. Section 44 C confers on the competent officer the power to recover the expenses incurred in the removal of the obstruction. Acting under section 44 D the competent officer can with the sanction of the state government remove even an obstruction or impediment to the navigation of any inland water which has been lawfully made or has become lawful by reason of the long continuance of such obstruction or impediment. It may also be relevant to mention here that the United Nations Convention on the Law of the sea (UNCLOS), 1982 while permitting the operation of structures in the EEZ area imposes certain limitations so that such structures do not cause interference to the use of recognized sea lanes essential to international navigation.[See article 60 of UNCLOS 1982]

It is also relevant to determine whether, to what extent and what kind of effect on a wild fishery is acceptable. Particular attention also needs to be given to water bodies near mangroves, ecologically sensitive sites and marine protected areas. The livelihood of fishing communities and their access to fishing grounds should not be affected by the positioning of cage aquaculture sites.

Once a 'cage aquaculture activity' is permitted in an area what are the rights which ensue in favour of the licensee?Uncertainty also exists regarding public

[2] Water extraction scenario does not arise in the context of cage aquaculture. The term 'land use', it is submitted should be broadly interpreted to mean even the 'use of the aquatic space'.

rights of access to waters near aquaculture sites, prevention of interference with aquaculture activities by other users of aquatic resources, ownership of non-farmed species in those areas where cage aquaculture related installations are made, and the problem of managing natural predators at cage aquaculture sites.

There is no clarity today with respect to the applicability of the domestic environmental legislations to the exclusive economic zone. Hence if a cage aquaculture activity is carried out in the EEZ area there are no clear policies or guidelines as to the precautions that need to be taken and the compliances to be made to ensure protection of the marine environment. In other words there are no legally established mechanisms to monitor the impacts of inputs used in cage aquaculture systems.

There should be clarity with respect to policies and legal framework on the 'seeds' to be used for cage aquaculture activities. The quality of the seeds should be adequately regulated from the 'aquatic health perspective', 'human health perspective' as well as 'livelihood / consumer perspective of the fish farmers'. The policies and legal framework should also have adequate components addressing areas such as 'choice of species of be used', 'siting', as well as 'management' of cage aquaculture systems. Particularly there should be a clear policy on the 'use of non-indigenous species' and species developed through 'genetic modification' (particularly 'transgenic varieties') as they can have serious implications for the aquatic environment as well as human health.

While developing policies and legal regimes incorporating the aforementioned components care should be taken to avoid overlapping requirements leading to extra costs and delays as well as confusion to the industry and the government. As things stand, it may not be feasible to spell out a detailed framework for the regulation of the cage aquaculture sector. To overcome such a difficulty broad and general propositions may, in the first instance, be enacted, which may subsequently be embellished on the experience gathered from the working of such law. Special care should be given to avoid situations leading to inconsistent interpretations and inconsistent decisions which can have a detrimental effect as far as the development of the cage aquaculture industry is concerned. In short, a streamlined and coordinated approach is required to ensure that policies and legislations adopted in connection with cage aquaculture are applied effectively and efficiently.

[3] Emphasis added

Use of remote sensing in the context of cage aquaculture

Trevor Platt, Phiros Shah, Grinson George, Nandini Menon, Nashad M., Maria Paul Thottan and Shubha Sathyendranath

Introduction

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

We shall find that the prime considerations relate mainly to the dispersal of toxic metabolites and unconsumed food; to cage damage by storms; to transient water masses of temperature and oxygen content outside the tolerance range of the cultured species; and to the incidence of harmful algal blooms. Another consideration is the supply and demand of essential fatty acids.

Site selection for cage aquaculture: the environmental context

In choosing suitable sites for cage aquaculture, a balance has to be found between the need for exposure (to disperse waste products) and the opposing need for shelter (to protect the cages from environmental damage).

Taking the specific case of Indian waters, we can make a rather complete physical characterization of properties relevant to degree of exposure using data collected mostly using remote sensing (average currents; sea-surface height; wind field; frequency of cyclones) supplemented by local data on tidal currents and possibly also by hydrodynamic modelling. It is clear that risk of exposure to cyclones is higher on the eastern side of India than on the western side (Fig. 1a) , and that the first three or four months of the year would be the period of lowest risk for short-term culture where the object was to enhance the weight or fat content of the fish before harvest (Fig. 1b).

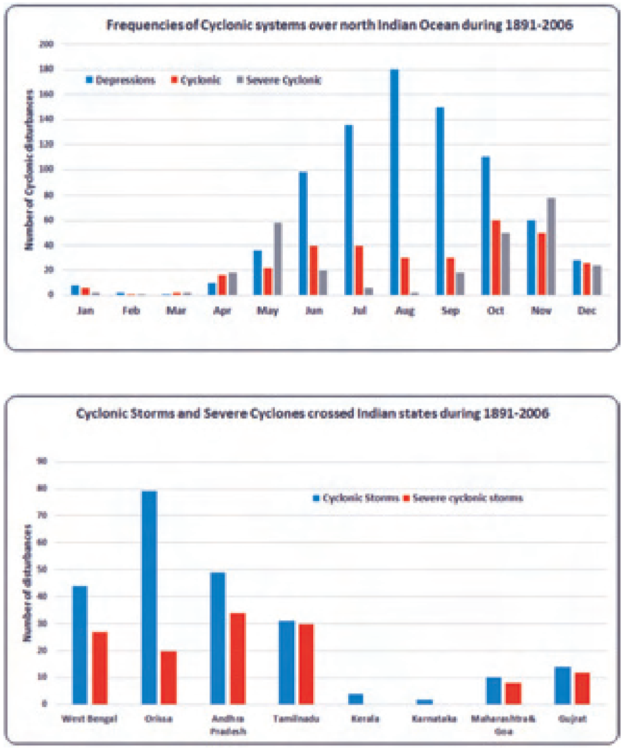

Fig. 1. (a) Cyclone and severe storm frequency at different coastal stations on Indian coast showing more energetic conditions on east coast compared with west; (b) Seasonal distribution of storms showing quietest period to be the first three or four months of the year. Data courtesy of Indian Meteorlogical Department.

On the coast of India, the strength of tidal currents increases from south to north (Fig. 2). These trends are the more important, given that their mixing effect (dissipation of tidal energy at the sea bottom) is proportional to the third power of the velocity.

Finally, one should not overlook the reduction in flushing that is consequent on the proliferation of cage installations themselves (David *et al*., 2014).

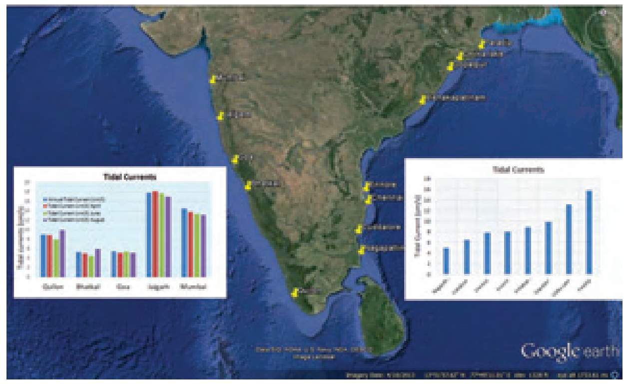

Fig. 2. Tidal currents at different coastal stations of India, showing increase of currents from south to north. After Susant *et al.* (2013); Subeesh *et al.* (2013).

Essential Fatty Acids (EFA)

Rations for organisms held in cage aquaculture are supplemented by EFA derived from harvest fisheries. It has been estimated that in 2010, 87% of the world's supply of fish oils would be used for aquaculture (Standiford, 2002). The sustainability of this practice remains to be demonstrated. Recently, a method of assessing the supply of EFA from the sea, using remotely-sensed data on ocean colour, was developed and implemented (Budge *et al.,*2014). It provides a potential way to compare supply and demand of EFA at the global scale (Fig. 3).

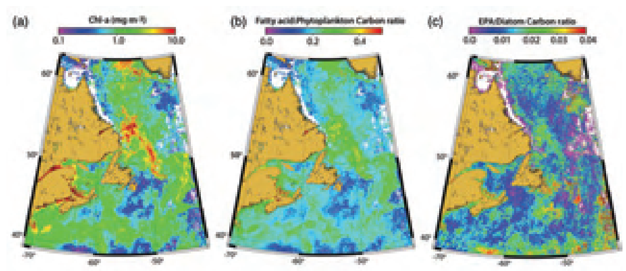

Fig. 3 (a) Chlorophyll-a concentration, (b) Ratio of concentration of total fatty acids to phytoplankton carbon, and (c) ratio of EPA concentration to diatom carbon. Results for North West Atlantic using remote sensing, from Budge et al. (2014)

The delivery to humans of EFA from the oceans usually depends on the harvest of fish, followed by the extraction of EFA therefrom. The potential yield of fish cannot exceed the new primary production (that component of the total primary production dependent on oxidized nitrogen as a nutrient source). New production can be measured at sea, or estimated from the total primary production. A method based on remote sensing exits (Sathyendranath, 1991).

The rate of new production will set an absolute upper bound on the potential yield of fish and therefore, proportionally, on the potential yield of EFA. The realized yield of fish and EFA will fall considerably below the absolute upper bound set by new production because of inefficiencies in the food web. The cumulative losses due to the inefficiencies will be greater for longer food chains. Feeding fish in cage culture is equivalent to adding another trophic level to the food chain. Using EFA in this way further decreases the trophic efficiency of production.

Case study: Avoidance of temperature and oxygen shock for cultured fish in the Philippines

A recent example (David *et al*., 2014) illustrates the practical use of remotely-sensed data in operational mode as an aid to management of cage culture. The fish concerned is the milkfish (*Chanos chanos*), the location is the Bolinao region of the Philippines. The fish are vulnerable to passage of transient, warm water masses, associated with reduced oxygen concentration: massive fish kills can occur, such as one in 2007 that brought losses of $9.5 million to the producers. An operational monitoring system was introduced. The threat of possible invasion by warm water masses could be detected early from imagery of sea-surface temperature. When this risk was considered high, daily monitoring of dissolved oxygen was carried out. If falling oxygen levels foretold an imminent fish kill, as happened in 2010, the fish were harvested early. Such prompt action, based initially on signals from remotely-sensed data, enabled the producers to reduce their losses by a factor of ten compared with the outcome in 2007.

Harmful Algal Blooms

Fixed aquaculture equipment is vulnerable to the incidence of harmful algal blooms. In ocean-colour imagery, these blooms can certainly be detected as perturbations of the chlorophyll field. But it is only in exceptional cases that the increased chlorophyll can be diagnosed as an elevated abundance of a particular species. During seasons when there is a risk of a harmful bloom, in situ monitoring of phytoplankton community structure should be undertaken, especially if there is an increase observed in the overall chlorophyll concentration. Once the presence of a potentially harmful bloom is detected, ocean-colour imagery is highly useful as a means to track the spatial extent, movement and eventual dissipation of the bloom.

An early example of the application of remote sensing during an outbreak of toxic algae in an area used for aquaculture occurred in Prince Edward Island (Canada) in 1989 (Sathyendranath et al., 1997). In this case, the responsible species was a diatom *Pseudo-nitzschia multiseries* producing domoic acid, a toxin that accumulated in filter-feeding bivalve molluscs, leading to human fatalities. At the time of the outbreak, there was no active ocean-colour mission in service, and aircraft surveys were made to collect multispectral radiance data, which were compared against field measurements to establish a local algorithm for chlorophyll retrieval. The areal extent and progression of the bloom could thus be followed (Fig. 4).

Summary

Remote sensing has much to offer to the cage aquaculture industry. First, it is helpful in the choice of sites for development of cage culture. Here, the opposing requirements of dispersion of waste products and shelter for the cages have to be balanced. The ability of remote sensing to deliver

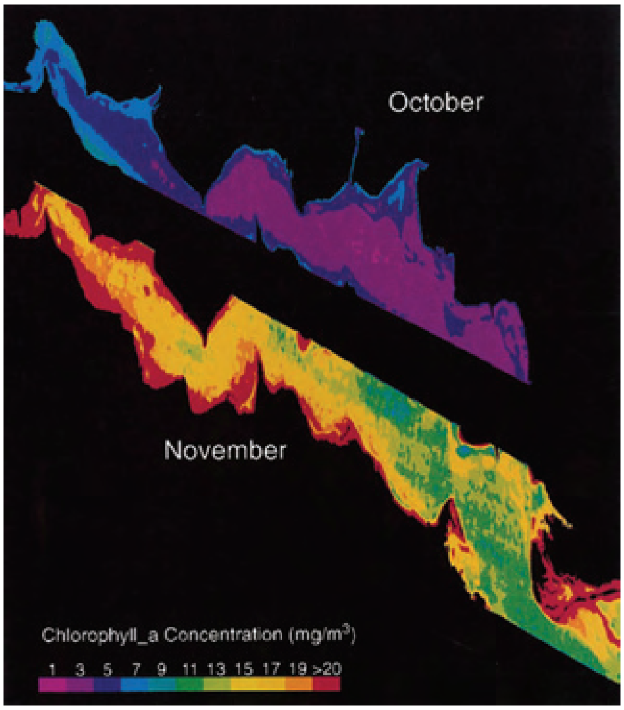

Fig. 4. Maps of phytoplankton distribution (in chlorophyll units) in the Cardigan Bay using aircraft remote sensing at the time of the outbreak of shellfish poisoning associated with the diatom *Pseudo-nitzschiamultiseries*

spatially-extensive data at high resolution is important, especially when complemented by numerical modelling. The most favourable period for cage deployments of less than one year can also be assessed from the seasonal wind field. Once the sites are selected, remote sensing continues to be beneficial in operational culture by providing early indications of the advent of water masses that are potentially antagonistic, either because of their physical properties or their microflora. Such warning gives producers the option to harvest their fish early and thereby minimize potential losses. The spatial extent and movement of unfavourable water masses or blooms can be tracked by remote sensing. Finally, new developments in remote sensing allow us to address the general issue of balance between supply and demand for EFA, and the effect on the balance of using EFA harvested from wild fish as a supplement to the diet of fish raised in cage culture.

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

Madhya Pradesh Fisheries Federation, striving towards a "Blue Revolution" for Income, Food and Nutritional Security of Fishermen through Increase in Production and Upliftment of their Socio-economic Status

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

The Madhya Pradesh Fisheries Federation (Co-Op) Ltd., Bhopal was established and registered under the Madhya Pradesh Cooperative Societies Act, 1960 in the year 1987 as an Apex body of the Fishermen's Cooperatives in the State. The mandate of the Federation is to work towards upliftment of Fishermen's Socio-economic status and strengthening of their collectives (Primary Co-operative Societies). The Federation is utilizing the available water resources in an efficient and scientific manner by introducing scientific method of reservoir development which soon resulted in better management of the resources that ultimately led to enhanced fish production and productivity. As per the Fisheries Policy (2008) of the Govt. of Madhya Pradesh, the Federation manages all water bodies having an area of more than 1000 hectare and works towards upliftment of the socio-economic condition of the fishermen living in the vicinity of the reservoir by engaging them in controlled harvesting of fish through their primary co-operative societies with an embedded ethos of conservation. The Federation also runs various welfare schemes for the fishers and their cooperatives and ensures their active participation in fish seed production and stocking of fish seed in the reservoirs, conservation of resources and endangered species so as to give them a sustainable income along with implementing various schemes of central and state governments. The Federation also strives to conserve resources of aquatic ecosystems by promoting and maintaining the diversity. The Federation tries to ensure the availability of fishery resources in sufficient quantities for present and future generations in the context of food security, poverty alleviation and sustainable development of small and poor fishers, who belong to the lowest strata in the society. The fishers and their cooperative with technical input from the Federation staff always work to conserve the local fish fauna and implement management measures to ensure that fishing effort is commensurate with the productive capacity of the

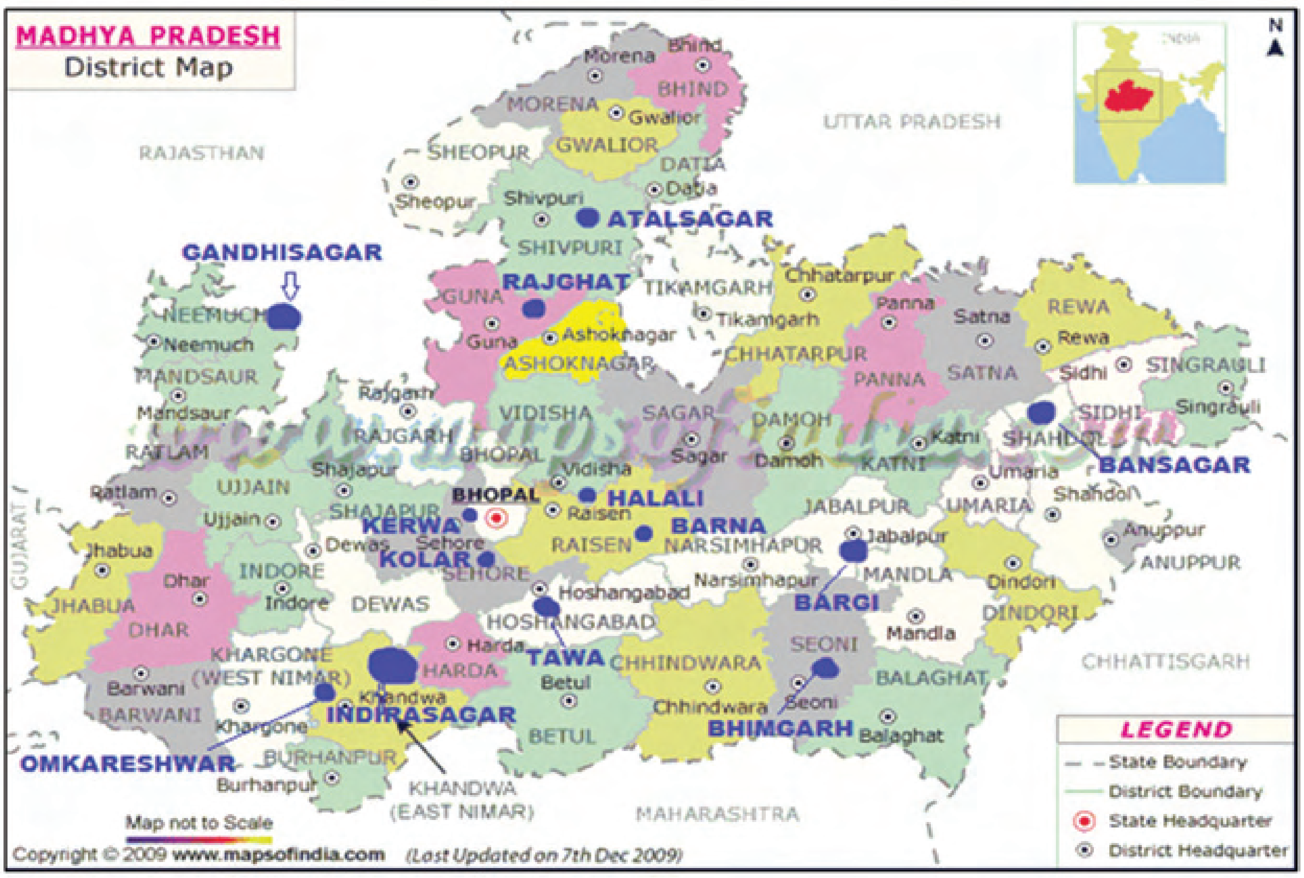

Fig. 1. Area of operation of the Federation

resources. At present the Federation has 18 reservoirs under its control with an average water area of 2.08 lakhs hectares and has 5 fish seed farms with hatcheries. The annual production capacity of spawn is about 400 million.

The Federation has also developed rearing area of about 36 ha on government land and took 197 seasonal village ponds within the periphery of the reservoirs with an area of 351 hectare to rear fish seed. This initiative of the Federation has resulted in maintaining a healthy fish seed stock in the reservoir. This innovative initiative has led to less mortality of the fish seed, injury to fish seed during long distance transportation, reduction in transportation cost and ensured large size seed stocking every year which gives the sustainable argumentation in fish production. The efforts put in by the Federation started to yield remarkable results and has made an economic and social impact in the life of fishermen and their families. The reservoir Fisheries in Madhya Pradesh has taken a quantum leap during the last 15 years. Some reservoirs under the management of Federation are producing the maximum fish per hectare compared to the other reservoirs in the country.

Table 1. Fishing resources of the Federation at a Glance

Sl	Name of Reservoir	Average Water Area in Ha
1	Indira Sagar	59029.00
2	Gandhi Sgar	41318.00
3	Ban sagar	31685.00
4	Bargi	16649.00
5	Tawa	12145.00
6	Omkareshwara	8000.00
7	halalai	4795.00
8	Barana	4791.00
9	Bhemgargh	2328.00
10	Kolar	1928.00
11	Kerwa	347.00
12	Rajghat - Chanderi	15676.00
13	Madhi kheda	3298.00
14	Harsi	1502.50
15	Mohni	1022.00
16	Rajghat -Sagar	1144.00
17	Mahi	1487.69
18	Sagad	1068.12
	Total	**208213.31**

Table 2. Comparative analysis of the rapid strides made in the reservoir Fisheries sector during last 10 years by the Federation

SN	Particulars	Unit	Year 2004-05	Year 2014-15	Percentage increase
1	Water area under management	Ha	128701	208213	62
2	Fish seed Production (spawn)	lac	974.50	2283	134
3	Fish seed stocking into the reservoirs	Lac	156.77	1032.11	558
4	**Fish production**	**Ton**	**1489.907**	**9952.381**	**568**
5	**Per hectare production**	**Kg/ha**	**11.58**	**50.75**	**438**
6	Registered cooperatives	Nos	159	183	15
7	Register members	Nos	7039	9677	38
8	Production per member per day	Kg	6.57	16.37	149
9	Income per member per day	Rs	79.00	397.00	402
10	Janshree Insurance	Nos	1401	6504	364
11	Accident coverage	Nos	4547	15415	239
12	Net income of the Federation	Rs lac	376.82	3303.29	776.54
13	Net profit	Rs lac	2.12	1439.13	67783
14	Payment of deferred wages	Rs lac	Not existed	372.00	-
15	Members under saving-cum-relief	Nos	Not existed	4214	-
16	Amount paid under 80% subsidy for nets and boats	Rs lac	Not existed	153.92	-
17	Amount paid under 50% subsidy for nets and boats	Rs lac	Not existed	75.00	-

(NOTE: One lakh is equal to one hundred thousand)

It is evident from the above facts that average per day income of fishers has seen a net quantum jump of 402% and per hectare production has shot up by 438%.

Some of the key achievement of the federation

1. **Increased income of fishers**
2. **Financial condition of federation**
3. **Fishermen welfare schemes**
   - 80:20 subsidy scheme
   - Deferred wages scheme
   - Encouragement for better performance
   - Shiksha protsahan scheme (encouragement for children's education)
   - Janshree beema scheme
   - Assistance for the grave disease scheme
   - Assistance for marriage of girl child
   - Fishermen credit card scheme
   - Jjaldeep scheme
   - Ex-gratia scheme
   - 50:50 Subsidy scheme
   - Accident insurance scheme
   - Saving cum relief scheme
4. **Increasing skill and knowledge of fishers**
5. **Linking fishermen to banks and their financial inclusion and welfare schemes**
6. **Increasing production and productivity of the reservoirs**

   a. **Production:** The average production of Federation is about 51Kg/ha/year with as high as 128 kg/ha/year in Gandhisagar which is much above the national average.

   b. **Stocking:** Federation made a stringent and scientific STOCKING POLICY wherein every reservoir is being stocked with fingerlings of major carp (IMC) every year with a minimum size of 70 mm in length. The number varies from 300 fingerlings to 1000 fingerlings per hectare depending on the average water spread area of the reservoir. This policy has been framed for augmentation of fish production.

   c. **Mesh size regulation**: To maintain the proper fish stock in the reservoir and to avoid exploitative fishing the Federation ensures that all fishermen should use fish net of size more then 40 mm. This way under size fish does not get caught.

   d. **Strict observance of close season:** To ensure proper auto-stocking as well as to maintain the breed able population in the reservoirs, the Federation enforces close season every year (i.e. from 16th of June to 15th of August). During this period the harvesting of fish remains banned to ensure auto stocking. At this time not only reservoir but whole river system up to the natural breeding grounds are kept under constant vigil so that fish could breed uninterruptedly and the juveniles of next progeny could survive in the reservoir.

7. **New initiatives**

   (A) Conservation of endangered fish species

   It has been observed that some species of local fish fauna are being depleted in the state, namely golden mahseer ***(Tor putitora)*** and chitala ***(Notopterous chitala)*** are of prime importance. Looking at the gravity of the situation Government of M.P. has declared the mahseer as state fish and instructed for taking care of this species.

In order to do this Federation has started a campaign to conserve and protect these species into the reservoir. For this purpose the juveniles of these species are being brought from other states and are being regularly stocked in the reservoir. Fishermen have also been involved in this initiatives and their awareness have been raised so that they will not catch the fish and if it is caught incidentally then they have been advise to release it live in the water.

(B) Cage culture- Through national mission for protein supplements (NMPS)

In an effort to boost the supply of fish and fishery products, the federation has also adopted innovative approaches that adopt ecosystem approaches and safeguard social rights aiming at conserving valuable resources for the benefit of present and future generations. The diurnal as well as seasonal variation of atmospheric temperature in the State varies from 2° C during winter to 45° C during summer. This condition poses limitations to culture fisheries. The reservoirs are used mainly for capture fishery. Usually the fish seeds of Indian major carps are stocked in the reservoirs every year. To augment fish yield Federation has started cage-culture in the reservoirs with the support of the Govt. of India under the scheme of National Mission for Protein Supplements (NMPS). Four cage units (each unit having 48 nos. of cages with 6mx4mx4m size) are installed in 3 reservoirs. The species opted for culture was *Pangasius sutchi*, as recommended by Project Implementation committee of NMPS. The results of the first crop are very encouraging (about 5 Ton fish per cage which is about 2000 Ton/ha). Federation established four units of cages having 48 cages per unit in three reservoirs namely Indirasagar (2 cage units - with latitude $20^0$16'41" and longitude $76^0$28'41"), Halali (1 cage unit - with latitude $23^0$30'05" and longitude $77^0$32'57") and Gandhisagar (1 cage unit - with latitude $24^0$40'51" and longitude $75^0$33'52"). Cages were installed in a caterpillar (staggered) manner to facilitate proper water flow in between the cages. The technical specifications of the cages are given in Table 1. Through competitive bidding cages were installed and operated on turn-key basis. The assignments were given to Indepesca Aquaculture Pvt. Ltd. Mumbai and M/s Fishermen, Itarsi (M.P.). There were 16 nursery cages and 32 grow-out cages in each cage unit. Initially the small seed of Pangasius (about 2 g) was brought from outside and reared in the nursery cages. After attaining the size about 80mm, it was shifted to the grow-out cages for further rearing.

(i) Feed and feeding

- At fry stage high protein 32% and fat 4% feed was used
- As size increased protein content in given feed reduced respectively to 28,24, 20% and after 300 g in fact even fat content also reduced to 3%
- Details of given feed and feeding mentioned below

(ii) Cage Nursery – fry received till 2 g

- Ground 32/4 feed was mixed with 5 eggs for every kg of feed and prepared dough

- These prepared dough were kept hanging in nets or tray for feeding
- Initially these were given 4 times a day, 8-10% of body weight

(iii) Cage Nursery – 2 g- 5 g

- 2 gm onward till 5 gm of size 32/4 (1.5 mm) feed was directly fed to fish
- Feeding frequency was 4-5 times a day, 8% of body weight

Table 1. Technical Specification of the Cages

MODEL – I (Internal dimension 6M x 4M x 4M)

Sl	Particulars	Specifications
A	**Cage Frame (As per drawing enclosed)**	
1	Main Cage frame (Trapezoidal shape)	GI pipe, "B" Class (ISI), 25 mm OD. Painted with anti corrosive, water resistant paints.
2	Inter connecting bracing	GI pipe, "B" Class (ISI), 22 mm OD. Painted with anti corrosive, water resistant paints.
3	Cat walk (about 2 feet above the water)	0.4 M wide, Chequered GI sheet (5 mm thick) on all sides.
B	**Floats**	New & Fresh PVC leak proof drums of 600 mm diameter & 900 mm length.
C	**Anchor & Mooring** (Diagonally opposite sides)	75-100 kg. Concrete / Granite / Black stone blocks of suitable dimensions with desired length of 20 mm nylon ropes.
D	**Cage nets**	
1	**Grow out Net**	Size 6 M x 4 M, depth 4 M, Bottom closed Flat, twine size 8 - 10 mm ply, Mesh size 15-20 mm, HDPE Knotless (UV treated) nett.
2	**Fingerling Net**	Size 6 M x 4 M, depth 4 M, Bottom closed Flat, twine size 8 or 10 ply, Mesh size 08-10 mm, HDPE Knotless (UV treated) nett.
3	**Cage Predator Net**	Size 7 M x 5 M, depth 5 M, Bottom closed Flat, twine size 8 or 10 ply, Mesh size 20 mm of 210 D Nylon Knotless nett.
4	**Bird Protection Net**	Size 8 M x 6 M, Flat, twine size 8 or 10 ply, Mesh size 20 mm of 210 D Nylon nett.
E	**Bottom frame(to retain the shape)**	Size 6 M x 4 M, 13 mm dia., GI pipe "B" class (ISI)
F	**Working Platform/raft**(One each for every battery)	Size 4 M x 4 M, made of 32 mm GI pipes frame & GI chequrer plate top provided with sufficient no of PVC barrels.
G	**Work & storage shed**	Size 8 M x 6 M, prefabricated frame, made of 32 mm GI pipes & GI chequrer plate top provided with sufficient no of PVC barrels with PPGI sheet roof & wall panels.
H	**Railling**	1'' GI pipe made two railings of 10 M length & 0.75 M height at the end of each battery.

MODEL – II (Internal dimension 6M x 4M x 4M)

Sl	Particulars	Specifications
A	**Cage Frame**	
1	Main Cage frame	HMW HDPE modular, floating, UV resistant cubical buoys, dimension 500mm x 500 mm x 400 mm (loading capacity:325kg/m^2)
2	Inter locking & bracing	Nylon nuts & bolts with metal free assembly.
3	Cat walk (about 2 feet above the water)	According to block size, not less than 0.5 M wide, anti skid surface on all sides.

B	**Anchor & Mooring** (Diagonally opposite sides)	75-100 kg. Concrete / Granite / Black stone blocks of suitable dimensions with desired length of 20 mm nylon ropes.
C	**Cage nets**	
1	Grow out Net	Size 6 M x 4 M, depth 4 M, Bottom closed Flat, twine size 8 - 10 mm ply, Mesh size 15-20 mm, HDPE Knotless (UV treated) nett.
2	Fingerling Net	Size 6 M x 4 M, depth 4 M, Bottom closed Flat, twine size 8 or 10 ply, Mesh size 08-10 mm, HDPE Knotless (UV treated) nett.
3	Cage Predator Net	Size 7 M x 5 M, depth 5 M, Bottom closed Flat, twine size 8 or 10 ply, Mesh size 20 mm of 210 D Nylon Knotless nett.
4	Bird Protection Net	Size 8 M x 6 M, Flat, twine size 8 or 10 ply, Mesh size 20 mm of 210 D Nylon nett.
D	**Working Platform/raft** (One each for every battery)	Size 4 M x 4 M, made of 32 mm GI pipes frame & GI chequrer plate top provided with sufficient no. of PVC barrels.
E	**Bottom frame (to retain the shape)**	Size 6 M x 4 M, 13 mm dia., GI pipe "B" class (ISI)
F	**Work & storage shed**	Size 8 M x 6 M, prefabricated frame, made of 32 mm GI pipes & GI chequrer plate top provided with sufficient no. of PVC barrels with PPGI sheet roof & wall panels.
G	**Railing**	1'' GI pipe made two railings of 10 M length & 0.75 M height at the end of each battery.

(iv)Cage Nursery - 5 g - 50 g

- 5 gm onward till 50 g of size 32/4 (2.0 mm) feed was directly fed to fish
- Feeding frequency: 4 times in a day, up to 6% of body weight by end

(v) Grow-out

- 50 g - 100 g
- 32/4 (2.0 mm) directly fed
  - Demand feeding, up to 4 - 5% of body weight
  - Feeding frequency: 2 - 3 times depending on climate
- 100 g -300 g
- 28/4 (4.0 mm) directly fed
- Demand feeding, up to 3% of body weight
- Feeding frequency: 2 - 3 times depending on climate
- 300 g - 700 g
- 24/3 (4.0 mm) directly fed
- Demand feeding, up to 2% of body weight
- Feeding frequency: 2 - 3 times depending on climate
- 700 g - 1,000 g
- 20/3 (4.0 mm) directly fed
- Demand feeding, up to 1.5 - 2% of body weight
- Feeding frequency: 2 - 3 times depending on climate
- Average production per cage arrived at 5,041.7 kg
- Average Body Weight of harvested fish arrived to 1.071 kg
- Total fish numbers harvested: 1,53,626
- Survival recorded,
- From 2 g (Cage nursery) till harvest: 52.97%

- From 50 – 70 g till final harvest (Within grow out): 74.58%
- Average Body Weight (ABW) of harvested fish: 1.050 kg

Sampling procedure & analysis

a. Sampling was performed on a fortnight basis in cages to check the growth rate and FCR. It was also required to adjust the daily feed ration as indicated by the feeding tables.

b. It was necessary to take the sample with least interference to the overall population, while ensuring that the sample was representative one.

c. It was thus required to lift the base of the cage and to take at least 30 fish in a scoop net when it was clear that the population was homogenous and all sizes were represented randomly in the sample. Although this caused some stress but it was unavoidable.

d. Care was taken minimize the time from lifting of the net until removal of the sample after which cages were dropped again.

e. The accuracy of the sampling was critical to the good management and progress of grow out and its profitability.

Size sorting procedures

a. There were two times when the number fish stocked in each cage needed to be adjusted,

i. The range of 100 grams (70 - 125 g) and

ii. The range of 450 grams (250 - 600 g)

b. The fish populations needed to be graded by size on this transfer (bigger to one cage and smaller to another) and the numbers were counted in order to check the survival and to adjust the record of numbers to the real value.

c. After the second grade the survival and numbers were checked when the cage was emptied for harvest.

d. The procedures for this grading again required skill in handling, minimum exposure to stress and the team worked on manual grading in the early hours of the day before temperatures rise creating stress to fish.

e. To avoid stress the full caged population, it was concentrated on a small beached of fish in a fold of net.

f. Fish were starved a day before grading commenced on that particular cage.

Splitting of population

a. The splitting of the cage population into to size groups when the population spread gets too large is basic requirement for maintenance of good FCR and to ensure that the infrastructure utilization is maximized. It required a lot of physical effort, while at the same time team effort is necessary. If concentration and controlled actions are not performed, damage and resultant disease and mortality can be inflicted on the population.

b. This resulted in a resistance to perform the grading and to leave populations from start to finish in the same cage.

c. This tactic will result in overall much lower production for the unit with higher FCR's, it is thus an essential part of the farm managers function to ensure that grading of sizes and transfers are daily event on the cage unit and well monitored.

Harvesting & selective harvesting

a. When cage populations reached harvest weigh determined by customer demand and production planning and the critical co-ordination of both of these aspects harvesting was initiated.

b. Harvested fish were transferred to a free moving harvesting cage which was afterward drawn to the bank of the lake to load on the transportation vehicle.

c. After each harvesting fish below the required size were transferred back to another cage to let them grown to market size.

d. It has been observed that there were few fishes that have not reached market size and remained stunted.

Problems

- It was difficult to observe the fish in cages. Sampling to observe may stress the fish and lead to secondary infections. Therefore, the observations during feeding, when fish come up to eat at the water surface was very critical. This day to day observation was essential to keep the healthy fish culture and increased harvest.
- Stress comes from water body, accumulation of feed, organic materials, livestock waste and pesticides in water may be harmful to fish. These factors change the optimum water condition and affect the caged fish. These things were avoided through an appropriate site selection and proper maintenance of the cage.
- Bio-fouling is very common in cage culture. It is caused by organisms that attach themselves to the structure of the net cage and restrict water exchange. Bio-fouling can be reduced by cleaning cages at the right time and applying anti- fouling paint on cage. Therefore, regular cleaning were performed.
- Accumulation of waste could happen mainly due to uneaten feed. It was managed by following practices :-
- To facilitate water exchange, large mesh size (40 mm) was used. Areas where there was gentle breeze were selected for cage installation so that circulation of water through cages was proper.
- Ideal exchange rate is one cage volume per every 30 to 60 seconds. This could be achieved by having caterpillar design for installation of cages. Place the broad side of the cage in to the prevailing wind to aid water exchange.
- Bottom of the cage should be kept 50 cm above the bottom of water body.
- Feed only as much as the fish will consume within 15 minutes. If fish do not consume the feed in 15 minutes or stops feeding, reduce or stop feeding until fish respond willingly to the feed.

Way Forward

- Maximize production from set of these 48 cages (designated 16 nursery + 32 grow out cages at present) it is advisable to procure some more grow out cage nets separately and increase grow out area or else these remains unused.
- Possible options of culturing other species (Tilapia, Seabass, other commercial species) shall also be worked out for these cages.
- Water quality to be monitored; Dissolved oxygen (DO) deficiency is not an issue for Pangasius as it is an air breather. However, to grow other species in cages it is required to monitor daily.
- Marketing strategy to be improved; species which can be marketed and sold at an average 400 – 450 g; to be surveyed for nearby markets and established before planning and taking up its culture.

Due to State's geographical conditions, it takes about 18 months to harvest the fish from the cages. The value of *Pangasius* in the market is low (sometimes below Rs.60 per Kg in the wholesale market) and as a result its production is not economically viable. In this context it is required either to decrease the production cost by use of local/low cost fish feed through new innovations or choose any other species of fish which may give high sale price. Availability of good quality seed at local level is also a problem. Initial investment in cages is also high. Therefore, low cost cage should be searched for which can bear the forces of waves and wind actions arising in large reservoirs. It has also been observed that the results of *Pangasius* culture in small ponds gives better results as compared to cage culture in reservoirs.

With this new venture a huge opportunity of getting high production of fish from the limited area within the reservoirs can be obtained. In Madhya Pradesh if we use 10% of the area for cage culture in reservoirs the fish yield can be augmented many fold thereby addressing the malnutrition problem of the people at large. With this the economic condition of the fishers can be improved to a great extent by using modern technologies and new scientific interventions.

Culture of prawn in reservoirs

Culture of Prawn (*Macrobrachium rosenbergii)* in freshwater along with capture fishery is a new and innovative practice started by the Federation in its Indirasagar and Bheemgarh reservoirs. Madhya Pradesh is a land locked state and its reservoirs are huge fresh water bodies but there is no estuarine water in the state. In this situation Federation collected the wild seed of Prawn from Bay of Khambhat (Downstream of Narmada River) through outsourcings and these are released into the reservoirs. Within a period of one year time the juveniles of Prawn has attained an average growth of about 200 gm each. During the current year the production of Prawn from these reservoirs are around 2500 kgs and the harvesting is still in progress. Due to this innovative activity of Mahasangh, a new window is opened for getting high value product from the reservoirs over and above routine capture fishery.

Fish health management in cage aquaculture

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Introduction

Finfish is the primary source of animal protein for humans in many parts of the world and per capita consumption of fish has been increasing from an average of 9.9 kg in the 1960s to 19.2 kg in 2012 (FAO, 2014). Growing global population, dwindling natural fish stocks, and the increasing demand are the major drivers for increasing fish production. Aquaculture remains the only option to meet these demands and globally, the share of aquaculture is projected to rise to 62% of the total fish production by 2030. However, considering the limitations of the traditional aquaculture systems due to environmental issues, carrying capacities etc., it has been recognized that cage culture, especially mariculture has many advantages. Over the years, cage culture has become one of the economically viable methods of large-scale production of high-value food fishes. Many stakeholders consider open sea activities such as cage and pen culture as the aquaculture system of the millennium. High-value carnivorous fish species such as groupers, barramundi, snappers and pompano are increasingly being raised in small cages in inshore environments. Further, there is a move towards offshore mariculture using larger and stronger cages in China (FAO, 2014). Production figures show that about 60% of coastal fish culture is contributed by cage farming and cage culture contributes more than 90% of all seabass and seabream production (Syda Rao, 2012). Although history of cage culture dates back to 1800s in Southeast Asia it was in 1950s that commercial level marine cage farming started in the region.

Cage culture - the Indian scenario

The first initiative on low volume brackishwater cage culture of seabass, funded by New Zealand Agency for International Aid (NZAID) was implemented through the fisherfolk Self Help Groups at Kodungallore in 2005-07 (Vijayan *et al*, 2007). Though the first open sea cage was launched in Bay of Bengal off Visakhapatnam coast in 2007 as a part of research and development (Syda Rao, 2012), reports are available on marine cage farming of fishes such as *Sillago sihama, E. hexagonatus* and *E. tauvina* way back in 1980s and 90s. In India, marine cage farming has become a prominent activity since 2008 and the Asian seabass *Lates calcarifer* has been the pioneer species for culture. Standardized hatchery technology, availability of hatchery-produced seed, good market demand and fast growth enabled appreciable adoption of cage farming by farmers. Another potential species is cobia *Rachycentron canadum.* According to Syda Rao (2012), among crustaceans, open cage farming of lobsters are proved to be economically remunerative.

Disease problems in cage culture

Although, cage farming has many economic advantages, like any other animal production system, diseases are one of the major limiting factors to the successful production. Increasing intensification and lack of adequate health management measures result in frequent occurrence of diseases. Since the basic cage culture practices are similar in all the regions, disease problems encountered will largely depend on the species being cultured, environmental conditions and management practices (Seng and Colorni, 2002). As in other aquaculture systems, environmental factors such temperature, salinity, dissolved oxygen, suspended particulate matters etc. are critical and any adverse changes in these parameters would make the fish susceptible to diseases. Similarly, crowding and handling stress and feed management also play a crucial role. Unlike closed systems, the risk of pathogen incursion through cohabiting animals and pathogen-contaminated water is more in open cage farms. However, like any other farming system, health management practices involving early detection of infection and prophylactic and therapeutic treatment are of paramount importance. Many of the biosecurity measures which are employed in land-based aquaculture systems will not have much relevance to cage farming, as the system is highly dynamic. However, a thorough understanding of pathogens, disease process, diagnosis, epidemiology and control measures are essential for better health management of farmed fishes in cages. As cage farming is in a nascent stage in India, the lessons learned in dealing with disease problems and their management in land-based aquaculture systems will be of immense use in cage farming in future. In this background, this article discusses various aspects of important pathogens/diseases of farmed marine and brackishwater fishes, especially those which are recorded from Asia-pacific region along with the challenges in managing these diseases in open cage system.

Viral diseases

Among the diseases with infectious aetiologies, viral diseases are the most consequential in aquaculture systems, and as new species of fishes are cultured, incidences of known and new diseases can emerge. Two major group of viruses, iridovirus (DNA virus) and nodavirus (RNA virus) have been reported from fishes reared in marine cage farms from different parts of the world.

Viral nervous necrosis (VNN)

Disease and hosts: Viral encephalopathy and retinopathy (VER) or viral nervous necrosis (VNN), is a serious disease infecting several species of marine fish. The disease is characterized by vacuolating lesions of the central nervous system and retina leading to significant losses, mostly in larval and juvenile stages. Although the disease primarily affects early stages, serious mortalities have also been reported in market-size and adult fish, such as Asian and European seabass, Atlantic halibutand seven-band grouper. Considerable variations have been noticed in the pattern of mortality. Further, morality is reported to be age-dependent where higher mortality occurs in larval stages,while in juveniles and older fishes it is low. In India the virus has been identified as a serious pathogen of hatchery-reared seabass, *Lates calacrifer* (Azad *et al*., 2005). Subsequently, many reports have been published on the virus from Indian fishes (Parameswaran *et al*., 2008; Binesh and Jithendran, 2013; Banarjee *et al*., 2014; John *et al*., 2014). The disease has been reported in more than 50 species, mainly marine fishes.

Pathogen: The causative agent was first isolated from striped jack, *Pseudocaranx dentex*, and the name striped jack nervous necrosis virus (SJNNV) was adopted and identified as a new member of the family Nodaviridae. The virus has subsequently been isolated from other fishes as well. Currently, the virus is placed under the genus *Betanodavirus* within the family *Nodaviridae*. These viruses are small (25-30 nm), non-enveloped and spherical. The viral genome consists of two segments of positive-sense single-stranded RNA (ssRNA). A 3.1 Kb RNA1 codes for replicase and 1.4 kb RNA2 codes for coat protein. Phylogenetically, four major genotypes have been identified based on a variable region of RNA2: designated: SJNNV-type, tiger puffer nervous necrosis virus (TPNNV)-type, barfin flounder nervous necrosis virus (BFNNV)-type, and red-spotted grouper nervous necrosis virus (RGNNV)-type.

Epizootiology and how it is significant to disease outbreaks?: VER infection is primarily transmitted horizontally especially via contaminated water. However, vertical transmission from broodstock to offspring has also been reported. Hence it is essential to screen the broodstock and ensure pathogen-free status before spawning because the success of farming depend on production and supply of VNN-free larvae and juveniles. Presence of wild reservoirs and use of infected wild caught seeds play a major role in disease dissemination. Betanodavirus can survive in sea water at lower temperaturesand even in frozen fish posing a potential risk. Further, surviving fishes can harbour the virus for prolonged periods and become lifelong carriers, transmitting the disease.In open water cages, transmission can occur easily through water current, boats and other appliances which will be used for transportation of men and material across cages. Further cohabiting wild fishes and the fish-eating birds can act as vectors.Water temperature plays a critical role in influencing the onset of clinical signs. This is especially true with VER outbreaks in farm-reared seabass and the infection is often known as 'summer disease'. Control and prevention of the virus is a challenging proposition, especially in open cages, as avoidance of exposure to the pathogen is difficult. However, rearing of juveniles originated from pathogen-free broodstock can minimize the risk of disease to a large extent. Health monitoring of fry should be carried out before stocking in the cages. Though chemotherapy is not available, effective vaccination strategy showed promising results in groupers.

Lymphocystis

Disease and hosts: Lymphocystis disease (LCD) is an iridoviral disease first reported in European flounder and later in many other fishes and is characterised by nodular skin lesions. The infected fish show cream-coloured nodular lesions on skin and fins and internally over the mesenteries and peritoneum. Although highly contagious, the disease follows a chronic pattern with limited mortality. Juveniles fishes is more susceptible. Infected fishes generally recover within a few weeks after the onset of disease outbreak and the lesions and scar tissue almost disappear. However, the virus has not been reported from India.

Pathogen: Lymphocystis disease virus (LCDV) is the causative agent of lymphocystis disease. LCDV is a member of the family *Iridoviridae.* Iridoviruses are large viruses with icosahedral symmetry having a diameter of 120–350 nm. The virus possesses an envelope derived from host plasma membrane. The genome consists of a single linear molecule of double-stranded DNA. The genome is 102,653 bp in length.

Epizootiology and control measures: The virus has wide host and geographical range infecting farmed fishes as well as ornamental fishesin Asia-pacific. It is transmitted horizontally through direct contact andstress factors can favour the disease. As there is no effective therapy available, the best possible option to prevent the disease spread.

Red seabream iridoviral disease

Disease and hosts : Red sea bream iridoviral disease (RSIVD) is a serious disease (OIE-listed) of cultured red seabream reported first from Japan and more than 30 species of marine fishes. However, it has been reported that the disease is caused not only by RSIV but also by infectious spleen and kidney necrosis virus (ISKNV). Affected fish show lethargy, severe anaemia, petechiae of the gills and splenomegaly. Histologically, it is characterised by the presence of enlarged cells in spleen, heart, kidney, intestine and gill of infected fish.

Pathogen: The causative agent, red seabream iridovirus (RSIV), is a DNA virus of icosahedral symmetry with a diameter of 200–240 nm. The disease is also caused by infectious spleen and kidney necrosis virus (ISKNV).

Epizootiology and control measures: The disease transmission is horizontal via water and vertical transmission and vectors of the disease have not been reported so far. Mortality depends on fish species, size and age of fish, water temperature and other culture conditions. Since therapy is not available, preventive measures are recommended. Effective formalin-killed commercial vaccine for RSIVD is also available currently.

Bacterial diseases

It has been suggested that successful aquaculture relies on better insight into the complex interactions between the cultured organisms and the bacterial communities present in the rearing systems. The microflora of the aquatic ecosystem comprises diverse taxonomic groups and the major groups of bacteria belong to *Vibrio* spp., and *Pseudomonas* spp., followed by *Alteromonas, Acinetobacter, Alcaligens, Photobacterium, Thiobacillus, Achromobacter, Flavobacterium, Aeromonas, Bacillus, Micrococcus,* etc. Although majority of the bacteria in the coastal marine water bodies are harmless, some strains belonging to genera of *Vibrio, Pseudomonas, Aeromonas, etc.,* are opportunistic pathogens to aquatic animals (Table 1). Among the bacteria that cause fish diseases, *Renibacterium salmoninarum*, the etiological agent of bacterial kidney disease, and *Mycobacterium* spp. can be classified as obligate pathogens since these are rarely found in the absence of a host. The environmental changes due to rains, temperature, discharges into water bodies and many unknown biotic and abiotic factors can all contribute to changes in the microbial communities. In addition to these, vast number of inputs such as feed, probiotics, immunostimulants, growth promoters etc., that go into the aquaculture systems can also bring about changes and shifts in microbial communities. Understanding the population structure and shifts in microbial communities can help in tracking the causes of outbreaks in aquaculture systems.

Vibriosis: Although a number of bacteria are reported to be associated with diseases in fish, only a few are responsible for large-scale mortalities. Bacteria such as *Vibrio anguillarum, V. alginolyticus, V. vulnificus, V. damsela, V. harveyi*, *Cytophaga-Flexibacter* group, *Aeromonas hydrophila, Pseudomonas fluorescens, Flavobacterium* and *streptococcus* have been implicated with major bacterial diseases in seabass.

Within the family vibrionaceae, the species which cause most serious diseases in finfish are *Listonella (Vibrio) anguillarum.* Vibriosis is the most significant disease of cultured and wild marine fish. The disease was first described in eels and is known to affect a wide range of marine teleosts. Vibriosis usually affects fish in salt or brackish water, especially in shallow waters during late summer when temperatures are high, *V. anguillarum,* the etiological agent of classical vibriosis causes typical haemorrhagic septicaemia. Fish show generalized signs of septicaemia with haemorrhages at the base of fins, exophthalmia and corneal opacity. So far, 23 serotypes of *V. anguillarum* have been reported to be associated with disease of which serogroup 2 is the most common strain causing epizootics world wide. Vaccines and chemotherapy are available for prevention and control of vibriosis due to *V. anguillarum*.

Streptococcosis

Streptococcosis has been associated with acute to chronic mortalities in several estuarine fishes. Infected fish display a disoriented whirling motion at the water surface and exhibit hemorrhages on operculum, around the mouth, at the base of fins and around anus. Abdomen is often distended with sanguineous fluid and exophthalmia is observed. The liver is pale and the spleen is deep red. The bacteria cause damage to the central nervous system, characterized by suppurative exophthalmia and meningoen cephalitis. Streptococcosis in fish is considered as potential zoonotic agent of human disease.

Presumptive diagnosis of streptococcosis is based on clinical signs, including the observation of Gram-positive cocci in the internal organs. Definitive diagnosis requires the determination of culture and biochemical characteristics of the isolate and serology. The bacteria can be identified by classical microbiological techniques while molecular techniques help in accurate and rapid identification.

Photobacteriosis

The disease is also called as pasteurellosis or pseudotubercosis is caused by *Photobacterium damsellae* sub sp. *Piscicida* (formerly *Pasteurella piscicida).* It has been reported in seabass, striped bass and sole in the Mediterranean countries and USA. However, there is no report of this disease in the Asian seabass. The disease is characterized by the presence of white nodules in the internal viscera, particularly in the spleen and kidney. Usually, heavy mortalities due to this disease occur during high temperatures and older fish are generally more resistant. The pathogen can be identified by classical microbiological techniques. Enzyme linked immunosorbent assay and polymerase chain reaction based techniques are also available. Vaccination protocols also have been developed.

Flexibacteriosis

It is also called as 'gliding bacterial disease', 'eroded mouth syndrome' or 'black patch necrosis'. The disease is caused by *Tenacibacterium maritimum (Cytophaga marina, Flexibacter marinus and F. maritimus)* and is reported from most parts of the world in a number of fish including sea bass. Environmental stress, particularly high temperatures aggravate the disease and its severity. Affected fish larvae have eroded and haemorrhagic mouth, ulcerous lesions on the skin, frayed fins and tail rot. Occasionally, the infection can lead to systemic disease. Clinical signs along with revelation of long rods in the wet mount or Gram stained preparations of gills or lesions by microscopy are used for presumptive diagnosis of the disease. Further confirmation is by isolation of the pathogen using classical microbiological techniques and identification.

PCR protocol for 16S rRNA gene target is useful in accurate detection of *T. Maritimum* in confirming the diagnosis as well as for epidemiological studies of marine flexibacteriosis. Vaccines have also been developed for the prevention of flexibacteriosis.

Mycobacteriosis

It is a sub-acute, chronic disease reported to affect more than 200 fish species worldwide. *Mycobacterium marinum*is the primary causative agent of fish mycobacteriosis and causes tubercle granulomas in cultured and wild populations of fish. A number of other *Mycobacterium* spp. are known to cause similar disease. Signs and symptoms of mycobacteriosis vary according to species of fish. Internally, the disease is characterized by white nodules (granulomas) in spleen, kidney and liver. External manifestations include loss of scales,

Table 1. Bacterial diseases reported from farmed marine fishes (taken from Seng and Colorni, 2002)

Disease	**Causative agent**	**Host species affected (Marine/brackishwater)**	
		Common name	**Latin name**
Gram-negative			
Vibrionaceae *Listonellaanguillarum*	Vibriosis	Yellowtail Amberjack Horse mackerel Red seabream	*Seriola quinqueradiata* *Seriola dumerili* *Trachurus japonicus* *Pagrus major*
Vibrio alginolyticus	Vibriosis	Greasy grouper European seabass Seabream	*Epinephelus coioides* *Dicentrarchus labrax* *Sparus aurata*
Vibrio parahaemolyticus	Vibriosis	Golden snapper Seabream	*Lutjanus johni* *S. aurata*
Photobacterium damsela	Pasteurellosis	Yellowtail Amberjack European seabass Seabream Red drum	*S. quinqueradiata* *S. dumerili* *D. labrax* *S. aurata* *Sciaenopsocellatus*
Enterobacteriaceae *Edwardsiellatarda*	Edwardsiellosis	Japanese flounder	*Paralichthysolivaceus*
Cytophagaceae *Flexibactermaritimus*	Saltwatermyxobacteriosis	Red seabream Greasy grouper Asian seabass Mangrove snapper Japanese flounder	*P. major* *E. coioides* *Latescalcarifer* *Lutjanus argentimaculatus* *P. olivaceus*
Gram-positive			
Streptococcus spp.	Streptococcosis	Greasy grouper Yellowtail Amberjack European seabass Red drum Tilapia (adapted to seawater)	*E. coioides* *S. quinqueradiata* *S. dumerili* *D. labrax* *S. ocellatus* *O. mossambicus*
Acid-fast pathogens			
Nocardiaceae *Nocardiaseriolae*	Nocardiosis	Yellowtail Amberjack	*S. quinqueradiata* *S. dumerili*
Mycobacteriaceae *Mycobacterium marinum*	Mycobacteriosis	Seabream European seabass	*S. aurat* *D. labrax*

accompanied by haemorrhagic lesions, extending to musculature in advanced cases.

Diagnosis is based on the signs and symptoms and identification of the pathogen. Smears of affected organs stained with Ziehl Neilsen's stain reveal characteristic acid fast mycobacteria. Precise diagnosis can be made by isolation and identification of the bacteria using selective culture media and phenotypic characterization including analysis of cell wall fatty acids and mycolic acids. Further, the etiology may be confirmed by 16S rDNA sequencing. The disease is asymptomatic for long time, stunts fish growth and it is impossible to treat affected fish by chemotherapy.

Parasitic diseases

Mortality associated with pathogens in wild fishes is seldom, as the balance between host and pathogen is rarely broken, except in situations where sudden fluctuations in environmental conditions occur. Wild fishes generally harbour many parasites but the intensity of infection most often remains very low in that it will not be consequential to the fish health. However, in confined conditions such as cages where the stocking density is very high and the resultant stress might act as a conducive factor for pathogens to cause diseases. High stocking densities coupled with fluctuations in environmental conditionsand/or stress can favour parasite proliferation leading to significant mortalities in net-cage-reared marine fishes.In aquaculture, there is an overall reduction in diversity of parasites and the general trend shows adecrease in infection with parasites having complicated/indirect life cycles.

Parasitic infections seriously impair aquaculture and the impact of parasites on marine finfish culture has been well documented (Table. 2). Except some protozoans, most of the economically important parasites infecting farmed fishes are ectoparasitic in nature, of which copepods such as *Lepeophtheirus* and *Caligus* are considered serious parasites causing mortalities. Ectoparasites feed on mucous, tissues, and blood/body fluids and the damage caused by their attachment and feeding activities may pave way for secondary infections. Major pathology associated with sea lice and other ectoparasitic infestation includes damage to the epithelial layer (skin & gills) resulting in haemorrhagic lesions on the skin and osmoregulatory dysfunction. They are also reported to act as vectors of some of the pathogenic viruses and bacteria besides making the fishes susceptible to secondary infection. Economic losses can be quantified in terms of direct mortalities, secondary infections, poor/reduced growth and expenses for treatment. Open cage farms facilitate easy transmission of parasites such as sea lice from wild to farmed fish and vice versa thereby causing unforeseen consequences in sympatric wild fishes. It has been reported that sea cages can becomes an unintended pathogen factory and can result in decline in wild fishes due to the spread of the parasites from the cage-farmed fishes. Among the other crustaceans, mortality associated with cymathoid isopod has also been reported in cage cultured fishes.

However, there is very little information available on diseases, especially of parasitic etiology from Indian sub-continent. The first record of serious mortalities in cage cultured fishes in India is that of a large-scale mortality in *Lates calcarifer* due to the crustacean isopod, *Cirolana fluviatilis* (Sanil *et al.*, 2009). Mortalities appeared one month after stocking and fish were found dead in cages with their flesh eaten away,leaving the remnants of skeleton. *C. fuviatilis* a voracious, carrion-feeding isopod widely reported from coastal waters was responsible for these mortalities. Though these isopods are bottom dwellers, in this case they have colonized the fouled net surrounding the cage and attacked the stressed

Table 2. Details of parasitic infections recorded from mariculture system in Asia-Pacific region (taken from Seng et al., 2006)

Parasite	Site of infection	Clinical signs
Ciliates		
Cryptocaryon irritans	Gills & body	Whitish spots on body surface, darkened body, lethargy, exophthalmia, increased mucus production, rub body surface against net.
Trichodina spp	Gills & body	Lethargy, non-feeding, pale gills with increased mucus production, rub body surface against net, hyperplasia andnecrosis of epidermis
Brooklynella spp	Gills & body	Lethargy, non-feeding, rub body surface against net, surface subcutaneous haemorrhage.
Henneguya spp.	Gills & body surface	Pale gills and hyperplasia.
Dinoflagellate		
Amyloodinium ocellatum	Gills & body	Fish gather at water surface or aeration outlet, rapid gillsurface operculum movement, pale gills, darkened body, increased mucus production in gills.
Myxosporean		
Sphaerospora epinepheli	Kidney, liver, spleen, & intestine	Loss of equilibrium, floating upside down, swollen abdomen & haemorrhages on mouth and body surface.
Microsporidian		
Glugea spp.	Internal organs	Swollen abdomen, black nodules on internal organs
Pleistophora spp.	Internal organs	Swollen abdomen, black nodules on internal organs
Capsalid Monogenean (skin flukes)		
Benedenia spp. *Neobenedenia* spp.	Gills & body surface	Darkened body, erratic swimming behaviour, rub againstnet, pale gills, lethargy and loss of appetite, opaque eyes, patches of "dryness" on scales or loss of scales at forehead(above the eyes), haemorrhage & necrosis on body surface.
Diplectanidmongenean (gill flukes)		
Pseudorhabdosynochus spp. *Diplectenum* spp.	Gills	Darkened body, rub against net, pale gills, lethargy, loss of appetite, excess mucus production.
Dactylogyrid monogenean (gill flukes)		
Haliotrema spp. *Dactylogyrus* spp.	Gills	Rub against net, devoid of scales at forehead (above eyes), pale gills, lethargy, loss of appetite, excess mucus production.
Microcotylid monogenean (gill flukes)		
Heterobothrium spp. *Heteraxine heterocerca* *Microcotyle spp. Bivagina sp.* *Choricotyle sp.*	Gills	Show no clinical signs except lethargy, loss of appetite,pale gills and anaemia.
Sanguinicoliddigeneans (blood flukes)		
Cruoricola lates *Pearsonellum corventum* *Cardicola sp. Paradeontacylix spp.*	Circulatory system	No obvious signs, affected fish gasp for air at the water surface, gill lamellae fusion & hyperplasia.
Crustaceans (Sea lice, isopods)		
Lepeophtheirus spp. *Caligus* spp. *Ergasilus* spp.	Skin & gills	Extensive hemorrhaging and skin erosion, lesions, Hyperplasia, congestion & erosion of gills

fish causing heavy mortalities. This is an example where parasites/pests that have not been previously considered pathogenic can cause serious mortalities under certain circumstances.

Infections with the dinoflagellate *Amyloodinium ocellatum* is considered one of most important diseases affecting cultured marine and brackishwater fish. Outbreaks by *A. ocellatum* have been reported in *Trachinotus blochii* and *L. calcarifer* from India. It causes 'velvet disease' in marine fish especially when kept under captive conditions/hatcheries and in cages. The parasites infect the skin/gills leading to mortalities.Wide temperature and salinity tolerances and high transmission potential make them more dangerous. The monogenean *Diplectanum latesi* has been known to cause mortalities in finfish. Heavy infection with *D. latesi* has been reported in the broodstock of *L. Calcarifer* (Rajendran *et al.*, 2000), but mortality associated with this parasite in cage-farmed seabass has not been recorded.

Although efficient chemotherapeutic measures are available against sea lice, most of the organo pesticides and avermectin derivatives effective against sea lice are highly detrimental to cohabiting crustacean fauna. Therefore, practical difficulties in the application of chemicals in open cages and their environmental consequences discourage their use. However, biological control of sea lice through cleaner wrasse (Family: Labridae) has effectively being used in salmon farming.

Lacunae/challenges in health management of marine fish culture

Control and prevention of infectious disease in aquaculture is a function of management. Incidence and severity of infectious diseases are very often dependent on the quality of aquatic environment in which the fishes live and the quality of feed they consume. While there is scope to manage some of the environmental parameters in land-based aquaculture, in mariculture or cage culture set up, this may not be possible. The environmental quality is almost similar to the sea in the mariculture or cage culture set up as long as there is no anthropogenic pollution. For most of the cage-farmed marine fish, trash fish are being widely used as feed and trash fishes are a potential source of pathogen transmission and this need to be monitored. When live feed is used, it should be ensured that they are free from pathogens and development of efficient pathogen-free feed is a requirement for the biosecure production of farmed fish.

One of the important sources of disease transmission to cage cultured animals from extraneous sources will be through transmission of pathogens through water and unfortunately this mode of disease transmission would be almost impossible to prevent. As more and more species diversification happens in aquaculture, characterisation of new pathogens, development of new diagnostic tools and understanding the basic epizootiology and host-pathogen interaction, especially the basic immune system of cultured species remain to be elucidated. However, as the number of cultivated species increases, the resources available for developing a comprehensive health management plan for these species will become scarce. Further, implementing effective health management strategies become difficult in most of the farming system, as majority of the farms are operated by small-scale farmers,who do not have adequate resources to implement these measures. Effective quarantine and biosecurity measures need to be implemented at the hatchery level to ensure that the fry/larvae of fish are pathogen-free before being introduced into the net-cages. Practice of using wild-caught fry for stocking should be avoided.

Developing highly sensitive diagnostic tools which can be used in a non-lethal way (without sacrificing the valuable broodstock) and also development of cost-effective farm-level diagnostics are essential to improve and sustaining cage fish farming.

Although cage-farming in India is presently relying only on native species, translocation of stocks across different geographical region needs to be done with proper care. Before introducing any new species for culture in the open cages, even the native species, a thorough profile of its potential pathogens and the possible management measures need to be identified. Culture of diverse species of fishes concentrated in an area will be a serious biosecurity issue, as this would enhance the chances of disease transmission. Maintaining proper hygiene, disinfection and biosecurity is quite challenging in open cage systems because of obvious reasons. However, proper cage maintenance by removing excess feed and suspended particulate matter, cleaning of fouling agents from the cages and frequent monitoring of the farmed animals and removal of dead or moribund animals from the cages play a crucial role in better health management.

Chemotherapy is effective in controlling many parasites and some of the bacterial pathogens. However, any attempt to apply chemicals or antibiotics in water should be strictly avoided. As in other aquaculture system, problems of drug residue, drug resistance, consumer safety, environmental safety will be great concerns. Further, as mentioned elsewhere, application of chemicals in open cages will have serious environmental consequences apart from non-target species safety. Development of vaccination will have great prospects in cage aquaculture, as unlike other intensive aquaculture systems, vaccination of individual animals is more practical and effective.

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3. ICAR-Directorate of Cold Water Fisheries Research, AnusandhanBhawan, Industrial Area, Bhimtal - 263 136, Distt: Nainital, Uttarakhand, India
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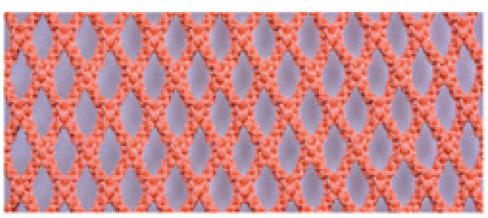


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