Souvenir

Ninth Indian Fisheries Forum

19 -23 December 2011
Chennai, Tamilnadu, India

Renaissance in Fisheries - Outlook and Strategies

Hosted by

Central Marine Fisheries Research Institute

P.B. No. 1603, Ernakulam North P.O, Kochi - 682 018, Kerala, India

www.cmfri.org.in

G. Syda Rao
Convener, 9IFF & Director, Central Marine Fisheries Research Institute
Kochi

PREFACE

I wish all the delegates and participants of the 9th Indian Fisheries Forum, being held at Chennai, a very warm welcome. It is reassuring to note that Indian fisheries and aquaculture industry , despite emerging challenges , is poised to embark greater strides upon the R&D as well as entrepreneurial bulwarks we have collectively built during the recent past. I am sure the 9th IFF with its theme "Renaissance in Fisheries: Outlook & Strategies" would deliberate pathways for achieving greater synergy among the stakeholders and plan strategies for capture fisheries and aqua-farming to achieve higher levels of sustainability and profitability.

It is my fervent wish that the forum would act as a Multi-stakeholder interactive platform that would help to charter future growth trajectories in the sector. The forum would also address the issues of impact of climate change and its mitigation, resource constraint and species diversification for the expansion of fish production activity; and encourage young scientists to undertake need-based and resource specific research.

This souvenir is the result of benevolent contributions from a galaxy of intellectuals as well as well-wishers. The articles written by experts provide a multidimensional perspective of the various developments taking place in the sector. We have been encouraged by the blessings received through messages from the different high dignitaries of the country. The enthusiastic support we have received from all our sponsors and advertisers is truly magnificent.

And may I take this opportunity to thank all those who have put their might in one way or other to bring out this publication in time and with zeal. I appreciate all the participants of the Exhibition organized on this occasion.

I wish you a fruitful and joyous occasion at Chennai and a meaningful New Year.

(G Syda Rao)

Smt. Pratibha Devisingh Patil
President of India

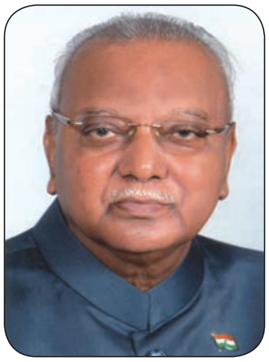
सत्यमेव जयते

MESSAGE

The President of India, Smt. Pratibha Devisingh Patil, is happy to know that the Central Marine Fisheries Research Institute (CMFRI), Kochi is organizing the 9th Indian Fisheries Forum (9th IFF) from December 19-23, 2011 in Chennai.

The President extends her warm greetings and felicitations to the organizers and the participants and wishes the Forum every success.

Officer on Special Duty (PR)



Sri. M.O.H. Farook
Governor of Kerala

सत्यमेव जयते

MESSAGE

I am happy to know that the Central Marine Fisheries Research Institute (CMFRI), Kochi, is hosting the 9th Indian Fisheries Forum in Chennai from 19 to 23 December 2011.

The main them of the Forum "Renaissance in Fisheries - Outlook and Strategies" is indeed topical as well as significant on every count.

I wish the conference and the commemorative publication all success.

(M.O.H. FAROOK)

Sri. Sharad Pawer
Minister of Agriculture & Food Processing
Industries, Government of India

सत्यमेव जयते

MESSAGE

I am happy to learn that the 9th Indian Fisheries Forum is being organized by Asian Fisheries Society (Indian Branch) and Central Marine Fisheries Research Institute (CMFRI) during 19-23 December 2011 at Chennai.

Being a major maritime state, India makes significant contribution to the global seafood basket as well as the national economy. The sector which provides livelihood and nutritional security to the millions of our country has been registering high annual growth rate in the total agricultural GDP. Innovative tools of science along with committed developmental efforts in the fisheries sector have enabled us to realize higher levels of productivity and sustainability as evidenced, for instance, by higher export earnings for the country. But there are new concerns like climate change, value addition, food safety and quality along the value chain and water use policies that need to be addressed lest they act as dampeners. I am sure the Forum with its timely theme "Renaissance in Fisheries-Outlook and Strategies" would come out with action plans to tackle these emerging issues.

I wish the 9th Indian Fisheries Forum all success.

(SHARAD PAWAR)

Dr. Charan Das Mahant

Minister of State for Agriculture & Food Processing Industries,
Government of India, New Delhi

सत्यमेव जयते

I am happy to learn that the Central Marine Fisheries Research Institute is organizing the 9th Indian Fisheries Forum (9th IFF) at Chennai during 19-23 December, 2011. The theme of the 9th IFF - **"Renaissance in Fisheries: Outlook & Strategies"** has very rightly been chosen at a time when global fishery is undergoing many transormations under the influence of different natural and manually generated interferences. Fish being a major and relatively cheaper source of animal protein, fish production through natural harvest and through aquaculture is a priority from the point of view of food security, employment generation and economic growth. India's position as a top fish producing country and the vest reserve of biodiversity in Indian waters, be it marine, brackish water of freshwater, makes it necessary to give extra impetus towards the growth and development of the fishries sector.

In the face of impending changes in the world's aquatic ecosystems, particularly due to the global warming, there is an urgent need to assess the status of the fisheries scenario in the country and elsewhere and bring together a diverse group of people like researchers, enterpreneurs, industrialists, economists, administrators and community stakeholders who will spearhead the development of this sector. The 9th IFF will provide the ideal platform to them.

I extend my warm greetings and good wishes to the organizers and participants and wish the 9th Indian Fisheries Forum a grand success.

(Dr. Charan Das Mahant)

Shri. Harish Rawat
Minister of State Agriculture, Food Processing Industries
& Parliamentary Affairs, Government of India

सत्यमेव जयते

It gives me immense pleasure to know that the 9th Indian Fisheries Forum (9th iff) with the theme "Renaissance in Fisheries: Out look & Strategies" is being organized at Chennai during 19-23 November, 2011.

India is one of the major fish producing countries in the world with third position in fisheries and second in aquaculture. In India, the fisheries and aquaculture have been recognised as a powerful income and employment generator to over 14 million fishers and farmers, majority of whom live in over 4,114 coastal villages, besides hamlets along major river basins and reservoirs. The 11 fold increase in the production of finfish and shellfish from 0.75 million tonnes in 1950-51 to 7.85 million tonnes in 2009-10 is a testimony to the contribution of the sector. The sector has high potentials for rural development, domestic nutritional security, employment generation, gender mainstreaming as well as export earnings. Greater synergy among the stakeholders and planning effective strategies for capture fisheries and aquafarming to build higher level of sustainability and profitability is the need of the hour. I am sure the scientific community attending the 9th iff will consider all these issues to sustain the sector and contribute to the nutritional security of the country.

On the occasion, I am extremely happy to extend my felicitations to the organisers Central Marine Fisheries Research Institute and greetings to the participants of the Forum.

Happy New Year to all.

Harish Rawat

Dr. S. AYYAPPAN
Secretary, DARE & Director General,
Indian Council of Agricultural Research

MESSAGE

It is a pleasure to learn that the Central Marine Fisheries Research Institute, (CMFRI), Kochi is organizing the 9th Indian Fisheries Forum (9th iff) with the theme on “Renaissance in Fisheries- Outlook and Strategies” during December 19-23, 2011 at Chennai. I am also happy to note that a Commemorative Souvenir on the latest developments in the fields of capture and culture fisheries in India is being brought out on the occasion.

Indian Fisheries is a robust sector of food production with an annual fish production of 8 million tonnes and export earnings of Rs. 13,000 crores. Resilience of fisheries and sustainability of aqua-farming are the key aspects to be focused upon, for deriving the ‘full fish power’ for enabling livelihoods of increasing number of people depending on the sector.

I am sure the 9th iff will throw up new ideas and provided a blueprint to enhance the profitability of this important sector of agriculture in the years ahead.

I wish the forum a grand success.

28th November, 2011
New Delhi

(S. Ayyappan)

Contents

Marine fisheries in India: The path ahead…..

G. Syda Rao
Director, Central Marine Fisheries Research Institute
Kochi

Fishery sector in India serves as potential source of nutritional and livelihood security for about 40 million people. The fish production in India is now about 7.85 million tonnes out of which, 3.32 is contributed by marine fisheries and the rest by inland fisheries. Marine fisheries in India has been showing a slow pace of growth during the last one decade. Though the production from the seas was stagnating, the annual total marine fish landings exceeded three million tonnes. However, meeting the requirements of the growing population in the years to come is a big challenge. To meet this challenge, we have to look into the seas again as it is the only available alternate food production system, which offers immense potential like sea farming systems. To harness the potential of sea farming/mariculture bio-secured facilities are to be developed on priority basis for broodstock management. Sea farming is an emerging field that requires massive investment to establish. On this line, CMFRI had initiated demonstration of open sea cage farming since 2007 and has nearly standardized the technology making it available to enthusiastic entrepreneurs.

Marine capture fisheries

The estimated landings from the marine capture fisheries from the peninsular region of the country (excepting Lakshadweep and Andaman and Nicobar isles) stands at 3.65 million tonnes (2009-10) with a quinquennial smoothed growth rate of 4.62%. In the past decade the inter-annual growth rate of landings have ranged from -10.7% to 12.8 %. The estimated harnessable marine resource potential of the Indian EEZ is 4.4 million tonnes at the present exploitation rates. The most liberal of the exploitation forecasts predicts that by 2030 the landings off Indian shores could reach upto 4.6 million tonnes. The trend based surveys have indicated that in the depth range upto 100 m, which contributes to about 86% of the total exploited resources, have practically no possibility of witnessing quantitative expansion of harvesting. However the depth ranges beyond 100 m have avenues of expansion, *albeit* more on qualitative terms. In this domain the possibility revolves around oceanic resources like tuna, billfishes and allied species whose combined potential is pegged at 0.2 million tonnes with the lucrative Yellow Fin Tuna contributing to the tune of 40% to it. Another feature of the decadal trends of landings is that among the various groups the contribution by pelagic and demersal fin-fish resources has shown marked increase while the crustaceans (shrimps) and molluscs are fluctuating around a flat trend. This adds relevance to the argument that quantum increase need not necessarily indicate increase in value of the products in the same vein.

The nine maritime states and two UTs in the peninsular region have retained their distinctive patterns when it comes to the dominance of sectors as well as resources primarily focused upon. Obviously resources with geographic loyalty like Bombay Duck, non-peneaid prawns, *Hilsa* etc. are being continued to be exploited in the North West and North East regions of the Indian coast as were in vogue. But at the same time certain other resources like Cat fishes which were quite dominant in the South West region have shown alarming downward slide in the past decade. One stand out factor in the recent past is the thick fast spreading of Oil Sardines in the South East coast which stands at 0.13 million tonnes in 2010. Among the states Maharashtra, Gujarat and Kerala have consistently recorded near total domination of fishing propelled by machines. In fact the out-board sector (motorized) which had galvanized the meandering fisheries of Kerala in late 80s has usurped place of prime with a strength of 1.3 units for each mechanized unit. The artisanal crafts, non-mechanised and out-board, dot the east coast more (73% and 60% of national count), whereas around 60% of mechanized crafts including trawlers are recorded against the west coast. Even in the North West region where the penetration of the core mechanized crafts was the least, the past couple of years have shown stark decline in the contribution by non-mechanised vessels. Another interesting feature of the fisheries is that the mechanized operations tend to be more multi-day in operation thereby further paling the demarcation between states' territorial boundaries. In the past couple of years, the focus is more on more per trip than more trips per month as even the motorized crafts slugging out for more days. This has a firm indication towards the compulsions of operational constraints. The fishermen families which are around 8.63 lakhs in the main land have 9.26 lakh active core fishers as per latest figures (2010).

The way ahead in marine capture fisheries management needs to focus on the following issues

(i) Expansion of fishery is no more uni-focal, ie. simple increase in quantity

(ii) Fast shrinking space for virgin avenues. Oceanic resources and deep sea resources are sure fire possibilities in the coming quinquennium

(iii) The intra-coastal geographic divide has little bearing on most of the resources exploited and it is in fact the marketing avenues which influence patterns in a telling fashion

(iv) Significant, sustained spread of not so high valued resources onto unconventional areas is noticeable. The role of environmental upheavals like global warming and climate change need special flagging

(v) The trend has been of sustained increase over the past six decades and more interestingly there has been no let down in the last five years. This augurs well for the validity of harvestable potential forecasts

(vi) Crafts tend to be prepared for longer trips and hence the increasing numbers, either as conversions/upgradations or as new build-ups, have to be seen with national resource availability at the back drop or bifurcated thereafter to local territorialisations

(vii) Ventures onto relatively unexploited domains like open sea cage culture may come in handy from the sustainability perspective of fishermen

Capture based aquaculture (CBA)

The room for increasing production from marine capture fisheries sector in relation to the growing demand for fish and fishery products is very limited. The marine capture fisheries production statistics indicates a stage of stagnancy and the current level of exploitation is fast approaching the potential of exploitable level. One of the most important factor for aquaculture development is the failure of wild fisheries to meet market demand. Aquaculture helped increasing the supply of fishes, improving the quality of fishes, developing new products for consumers which all in turn increased the per capita consumption of seafood.

Capture based aquaculture uses wild seeds or juveniles to stock in aquaculture facilities for ongrowing purposes. Capture Based Aquaculture accounts for about 20% of the total quantity of food fish production through aquaculture – mainly mollucs and some high valued finfish. Capture based aquaculture constitutes an alternative livelihood for local coastal communities and can contribute significant economic returns in those regions with depressed marginal economies. The collection of adult organisms is a special case related to the development of captive broodstock used for breeding in hatcheries.

Conflicts between aquaculture and commercial fisheries have been reported on space-related issues from various locations around the world. There is general fear that development of open water aquaculture will hinder the fishing activities of the traditional/local fishermen. Despite the potential for conflicts, adequate coastal zone management can lead to the development of synergies between aquaculture and traditional fisheries. In areas with declining wild catches and increasingly restrictive fishery regulations, aquaculture may help increasing production and providing livelihood opportunities for fishermen. Open ocean aquaculture may also provide unique opportunities for commercial fishermen either as a new occupation or a business that could complement their fishing practices since they already own vessels and have the maritime skills and knowledge of local oceanic and weather conditions.

Worldwide aquatic wild stocks and their ecosystems are in a fragile state. The growing importance of aquaculture production should be a way to relieve the fishing pressure on wild stocks and foster the maintenance of biodiversity whilst satisfying the growing market demand for aquatic products. Aquaculture can influence fish stocks through its use of wild fish stocks for inputs, such as feed, broodstock or juveniles. Dependence of fish meal for the production of aquaculture feeds is one of the major negative effects of aquaculture on fisheries. Aquaculture can also influence wild fish stocks through intentional releases. It has been used to replenish or enhance fisheries through purposeful release of juvenile or adult fish. Aquaculture can enhance fisheries habitat through development of infrastructure like oyster farms, fish cages and pens, or in some cases displace wild fish through its use of habitat. Aquaculture may cause the transmission pathogens to wild population and accidental escape of non native fishes from culture facility may affect the biodiversity of the farming region.

Fisheries socio economics and welfare

Marine fisheries sector in India provides employment to about three million people comprising 1.3 million of active fishermen, 1.50 million in the secondary sector and the rest in the tertiary sector of fisheries. The sector also supports the livelihood for about 18-20 million people.

The estimated marine fish landings in 2010 was 3.07 million tones (CMFRI, 2011). The gross value of the marine fish landings at the landing centre level is estimated at Rs.19,753 crores and at the retail level at Rs.28,511 crores (SEETTD, 2011). The private capital investment in fishing equipments has increased from Rs.10,352 crores in 2003-04 to Rs.15,496 crores in 2009-10. The per capita investment per active fisherman estimated at Rs.3,11,799 in the mechanized sector, Rs.38,870 in motorized sector and Rs.17,205 in the non-mechanized sector.

Fish & fish products recorded the highest increase in price among all food commodities-transforming from a poor man's food to the luxurious food item. The percentage share of fishermen in consumer rupee (PSFCR) ranged from 40% for Oil Sardines to 80% for Seer fish in private marketing channel. Wherever Self-Help Groups (SHGs) or cooperative fish marketing exists, PSFCR is consistently above 70% for all varieties.

Domestic marketing system requires more attention on modernization including quality control. There exists inadequate coastal infrastructure for domestic fish marketing compared to the commercial landing centres. This has led to polarization of harbour based infrastructure development and isolation of small centres.

High level of occupational risks are reported and also inter and intra sectoral marginalization. There is a lack of positive attitude towards non-fisheries livelihood options. The following aspects of fishery socio economics have to be considered for marching ahead.

- Formulation of a cogent Marine Water Leasing Policy
- Identification of suitable mariculture sites and central sector schemes for community oriented mariculture enterprises (as Open Sea Fishery Estates)
- Biomass augmentation through FADs, artificial reefs and marine parks
- Promotion of export oriented marine ornamental fish culture as a cottage industry and development of Special Fishery Enterprise Development Zones (SFEDZ)
- Empowerment of fisher women capacity building interventions through training programmes
- Incentives for value addition enterprises
- Investment for coastal infrastructure development (through PPP mode)
- Modernization of domestic fish markets
- Special banking schemes for small scale fishery-related enterprises
- Compulsory registration of craft and optimization of fleet size
- Mandatory sea safety measures
- Introducing new insurance schemes focusing fishery sector
- Development of bio-shields, installation of early warning systems and strengthening PFZ delivery
- Integrated Coastal Zone Development including Responsible Coastal Tourism

Training and capacity building

Great many people are dependent on marine fish as a livelihood source and the fish resources are being over-exploited. Any natural resource which is continually exploited at such high levels needs administrative and management inputs.

Management of marine fishery resources is a complex science. The large knowledge base and expertise built up over the years by CMFRI can be used to enlighten the interested stakeholders through short term training course of 1-2 months duration on topics such as marine fisheries management. Such courses will benefit fisheries managers and administrators and entrepreneurs in fisheries sector and will result in the creation of a new generation of fishery managers.

Milestones reached during the eleventh plan (2007-12)

1. Mariculture through open sea cage culture:

Open sea culture of fin fishes and lobsters was initiated at Veraval, Mumbai, Karwar, Mangalore, Cochin, Kanyakumari, Chennai, Kakinada, Visakhapatnam, Srikakulam and Balasore. Very good success was achieved for farming of seabass at Balasore and lobster at Vizhinjam. Other experiments with mullets and polyculture are in progress.

a. Farming of spiny lobster, the most sought after species of shellfish in the international market, was carried out in open sea cages and successfully harvested in February 2010 at Mandapam and Kanyakumari for the first time in the southern coast of the State of Tamil Nadu. The cost of production per crop was Rs.95,000 including Rs.67,000 as the production cost which included the cost of juveniles, feed, labour and others. The yield of lobsters through a crop could be sold for Rs.2.40 lakh, realizing a net income of Rs.1.46 lakh. It had been proved that cage farming of spiny lobsters could pave the way for the development of commercial level farming ventures in the region through Self-Help Groups. CMFRI would provide assistance for an economically viable and alternate livelihood option for fishermen.

b. **The harvest of the integrated fish farming in cage under** the NFDB sponsored project was carried out by CMFRI at **Moothakunnam** near Cochin during **June 2010**. The seedlings of mullet *(Mugil cephalus)*, seabass *(Lates calcarifer)* and the pearlspot *(Etroplus* spp.*)* with an average weight of 40-60 g were stocked in 6m dia HDPE cage. The fishes attained 300 - 600 g in weight during a period of six months. The harvested fish were handed over to the beneficiaries who auctioned them at the site.

c. CMFRI achieved record growth rate for seabass at Karwar (June-July 2010). The Asian seabass *Lates calcarifer* stocked in the cage under the project "Open sea cage farming of finfishes/shell fishes" in the marine cage farm of CMFRI at Karwar achieved a record growth rate with a high FCR which is considered as one of the best FCR obtained anywhere in the world for seabass culture. The 2,500 number of seeds introduced in the cage with an average weight of 9 g reached 850 g in weight in 135 days.

2. At Mandapam Regional Centre of CMFRI a major breakthrough in Cobia *(Rachycentron canadum)* breeding and seed production was achieved. Successful broodstock maturation of Cobia was obtained in sea cages for the first time in India by feeding with suitable broodstock diets. Methods for induced breeding were also developed and successful spawning and larval production were achieved. The rearing of larvae is in progress and shortly the techniques for successful seed production will be standardized. The hatchery production of Cobia fingerlings can pave the way for large scale seacage farming of Cobia in our country.

   Cobia F1 : The Cobia seed, which were produced during March 2010, attained a size of about 15 kg by September 2011. They also matured and spawned resulting in seed production. Cobia seeds are also continuously produced and the farm trials are being carried out at different locations. This is an excellent species for open sea cage culture.

3. **Pompano *(Trachynotus blochii)* broodstock and seed production:** This is achieved for the first time in India. It is a rare fish and the world aquaculture production is only 300 tonnes. The species tolerates wide salinity, grows fast and highly suitable for pond farming. Continuous seed production is being carried out and farm trials are going on at different locations.

4. **Oceanic squid:** The Indian marine fisheries industry has little room for growth, with most coastal stocks fished to their maximum potential base. One among the oceanic fish stocks of India with huge potential is the oceanic squid with a fishable stock of nearly 1.5 million tonnes from the Arabian Sea alone. The ommastrephid deep sea flying squid, *Sthenoteuthis oualaniensis*, is known as the master of the Arabian Sea, because of its high abundance, large size, short life-span, fast growth and near monopoly of the higher trophic niche.

5. **CMFRI data base recognized:** CMFRI's marine fisheries data base is recognized by the Ministry of Agriculture as the official marine fisheries data of the country. This recognition was regained after a gap of 40 years.

6. **E-prints@cmfri:** CMFRI launched Open Access Institutional Repository, 'Eprints@CMFRI' for its scientific publications since 1948. More than 9,000 scientific publications by the Institute's staff members are digitized and uploaded in 'E-prints@ CMFRI'. The repository can be accessed from the Institute website; "www.cmfri.org.in" and users anywhere in the world can freely download the articles. 'E-prints@CMFRI' features the facility of searching the articles by year, author, subject, document type or division. Users can freely download full-text as most of the documents are directly accessible. 'Request Copy' forms can be used for documents to which direct full-text download is restricted due to publishers' embargoes. The significance of the repository is that it acts as a showcase for Institute research and enhances the professional visibility of the scientists of the Institute. Now all CMFRI publications are available online and the scientific output of the Institute is reaching global audiences.

   Repository was created using open source software developed by the University of Southampton at UK. For global visibility, the metadata of the repository is made available to search engines like

Google, Google Scholar, OAlister, Base, Scientific Common and Scirus. This Repository is listed in the Registry of Open Access Repository, UK, Open DOAR (Directory of Open Access Repository- http://www.opendoar.org/), UK and Avano OAI Harvester. This has placed CMFRI as the first ICAR Institute to reach this stage. CMFRI also ranks first at national level and fifth at global level among the open access repositories on marine sciences. It ranks 304th place in Web of World Repositories. In India CMFRI is in 3rd place as published by the *Consejo Superior de Investigaciones Cientificas* (CSIC) – the largest public research body in Spain. The repository places 90th World Rank in Google Scholar Search.

7. **Fish Watch:** CMFRI has initiated a new system of field information dispensation on a near real time basis. As the first phase of this effort, the fish landing figures and the landing centre price range of important resources at six major fishing harbours of the country are being published as "Fish Watch" in CMFRI website. The landing figures are given in kg starting from 12.00 noon of the first calendar day to 12:00 noon of the subsequent day. These figures are updated at 1600 hrs on working days.
8. **National Marine Fisheries Census-2010:** The National Marine Fishery Census was commenced on April 16, 2010 across the country and was completed on May 15, 2010.
9. **Launching of CMFRI Trademark 'Cadalmin':** The Central Marine Fisheries Research Institute has officially registered a trademark entitled 'CADALMIN' for the products and services of the institute.
10. **CMFRI launched two products namely, Cadalmin TM Green Mussel extract (GMe) and Cadalmin TM Varna-Ornamental Marine Fish Feed.** The Cadalmin TM Green Mussel extract (GMe) was launched in March 2010. The product contains 100% natural marine bioactive anti-inflammatory ingredients extracted from green mussel. GMe is an effective green alternative to synthetic non steroidal anti-inflammatory drugs (NSAIDs) to combat joint pain/arthritis and inflammatory diseases in humans.
11. **Hatchery production of the green mussel *Perna viridis*:** Nearly one lakh spat of *P.viridis* were produced in the marine hatchery at Regional Centre, Visakhapatnam. This is done for the first time in India where large scale spat production in the hatchery has been achieved. This is significant to the mussel farming industry since farmers are now looking forward to the supply of mussel seed from hatchery to meet the increasing demand of seed for the expanding farming activities especially in northern and central Kerala.
12. Preparation of National Plan of Action on sharks was initiated in collaboration with Bay of Bengal Programme – Inter-governmental Organization with Sri Lanka, Bangladesh and Maldives as other participating countries.

The way ahead.....

Marine fisheries, though stagnant now, will continue to be the significant component of the capture fisheries sector in the days to come. In future it will become mandatory to shift from an open access to a regulated regime which in turn demands the establishment of a scientifically informed marine fisheries management system. In the Indian context, management regulations are possible only by considering the socio-economic conditions as well as the intricacies of the multi-species tropical ecosystem. There is need to develop such stock assessment tools that are more sophisticated but sensitive not only to the tropical bio-social reality being manifested both in the inshore and offshore sectors but also the looming effect of climate change. It is also a fact that the major portion of Indian marine fisheries is contributed by the artisanal sector. Providing alternate options of production of fish for the coastal fishermen will be the prime requirement. The orientation of research needs to be on production technologies. A concerted effort by the Institute on development of viable farming methods by taking into account the environmental considerations, biotechnological interventions, biodiversity implications and socio-economics is needed with a vision of enhancing coastal production through seafarming. The Institute has identified appropriate strategies to overcome these constraints and achieve our goal. The fundamental tenet that guides the envisaged vision is "Better Science for Better Fisheries". A networked constituency of informed stakeholders holds the key for future developments in the sector. Some of our thrust areas to achieve the above development initiatives are given below:

- Development of a model for chlorophyll based forecasting of fish and potential yield
- All India Coordinated Research Project on mariculture
- Facilitating a scientifically informed marine fisheries management system. Establishment of a National Fisheries Grid-GIS Platform for strengthening the National Marine Fisheries Information System
- Assessing the health of marine environment and the impact of climate change on marine fisheries and mariculture

- Developing a comprehensive model on climate change and marine fisheries to build different scenarios and predict fish abundance and fish catches. The impact of climate change on mariculture also needs to be addressed
- Estimation of biological reference points (or optimum harvesting strategies) for realizing long-term sustainable yields of large pelagics
- Scaling up sea farming: to establish mariculture as a substantial seafood production sector
- Stock enhancement of depleted finfish and shellfish stock
- Establish a number of bio-secure brood bank to produce seeds of important high value marine fin fishes at a cheaper rate on a large scale to facilitate large scale open sea cage farming
- Conservation of endangered, threatened and vulnerable marine living resources
- Capacity building for process optimization and product development of fish feeds using the state of the art technologies leading to the imitation of nutrigenomics
- Development of health management packages for the targeted candidate species while formulating viable technology packages for these species
- Explore and exploit the possibilities in marine bioprospecting
- Developing molecular markers of finfish and shellfish of commercial and mariculture importance
- Valuation of ecosystem services
- Assessing the social cost benefit impacts and the economic performance of fishing methods
- Constant monitoring of the emerging value chain dynamics, globally as well as regionally
- Policy frame work for marine capture fisheries, deep sea fisheries, island fisheries, coastal mariculture, environmental security, common property resource utilization, sustainability issues, food safety and WTO commitments for India

A. P. Sharma

Recent advances, issues and strategies for research in inland fisheries - Perspectives of CIFRI

A. P. Sharma and Pradeep K. Katiha
Central Inland Fisheries Research Institute, Barrackpore, Kolkata – 700 120, West Bengal
E-mail: apsharma1@gmail.com

Introduction

India has inland waters of varied dimensions consisting of rivers, reservoirs, wetlands, estuaries, lakes, etc. They form important fishery resources of our country. The magnitude of these water resources is given in Table 1.

Table 1. Inland open waters in India

Water resource	Magnitude
Rivers	29,000 km
Mangroves	3.56 lakh ha
Estuaries	3.00 lakh ha
Estuarine wetlands *(bheries)*	39,600 ha
Backwaters/lagoons	1.91 lakh ha
Large and medium reservoirs	16.68 lakh ha
Small reservoirs	14.87 lakh ha
Floodplain wetlands	3.54 lakh ha
Upland lakes	7.20 lakh ha

For past few decades the fish production from the rivers has declined. The conditions to sustain riverine fishery have further deteriorated due to increasing population, irrational methods of fishing, siltation and manmade modifications, rising environmental degradation and reduction in minimum water flows. The reservoirs and wetlands are the other important resources having greater potential for enhancing fish production and productivity and providing livelihoods to millions of people. Multiple use nature of majority of these waters with multiple stakeholders are the major constraints to harness their production potential. It has adversely affected the social and economic status of traditional fisher community. Therefore, we have to ensure that our open water fishery maintains existing sustainable stocks and at the same time develop the strategies to enhance productivity in large impounded waters.

CIFRI has played a pivotal role in bringing blue revolution in our country through its technologies of composite fish culture and induced breeding. Since 1987, it is devoted to conduct research to develop inland open water fisheries in the country. Its efforts are focused on conservation of original fish germplasm in rivers and estuaries and enhancement of fish production and productivity of reservoirs and wetlands through fisheries enhancements using ecosystem based fisheries management approach.

The present paper outlines the status of the inland open waters fishery resources, recent achievements of CIFRI and issues and strategies for future inland fisheries research in the country. These are spelt out for different inland open waters.

Rivers and estuaries

Our riverine fishery resources comprise five major river systems, *viz.*, the Ganges, the Brahmaputra and the Indus in the north and the Peninsular East coast and the West coast in south. Fourteen large rivers cover 83% of the drainage area of the country. The next group of 44 rivers constitutes another 7% of the total area and the rest 10% is constituted by many minor rivers. These together constitute a network of over 29,000 km in length. The potential of riverine systems as fishing resource varies from stretch to stretch, between the rivers and also within the river. CIFRI has developed the technology for spawn collection from the rivers. It has been well adopted by the riparian community and provided livelihood to a large number of fishers. It also contributed to improve the quality of fish seed for aquaculture by providing genetically improved natural fish seed.

The estuarine fisheries zone of India includes 3.56 lakh ha of mangroves, 3.00 lakh ha of estuaries, 39,600 ha estuarine wetlands *(bheries)* and 1.91 lakh ha backwaters/ lagoons. The Hooghly-Matlah estuary is the largest with an area of 2,34,000 ha followed by Narmada estuary with 30,000 ha, Godavari estuary with 18,000 ha while Mahanadi estuary is only 3000 ha. Among different estuaries the largest fish production was recorded from Hooghly-Matlah system.

The major research achievements of the institute in rivers and estuaries during last five year period are:

- Recognizing invasion of exotic fish species in river Yamuna as one of the major reasons for decline of IMC due to habitat deterioration
- Understanding the impact of river linking (Ken and Betwa river) on fisheries and fish habitat
- Scientific information on ecology, biodiversity and fisheries of major river systems in the country facilitating the prediction of likely changes in ecology and fisheries of the river due to habitat alterations
- Assessment of environmental flows in rivers. Environmental flows requirement during lean season for maintaining the ecological integrity of the river Teesta, (downstream of the Teesta Hydropower Power-4), in Sikkim was estimated at 18-20 cumec
- Distribution of fish catch in Hooghly-Matlah estuary according to salinity regime, type of fishing gears and season
- Data on ecology and fisheries of Hooghly, Narmada and Krishna estuaries; Chilika, and Pulikat lagoon for the development of ecosystem-based management plan. Documentation of the fisheries and bio diversity of Subarnarekha, Mahanadi and Godavari estuaries
- Assessed efficacy of fish passes on barrages in Mahanadi river system
- An interactive CD on algal diversity of Hooghly-Matlah estuarine system has been developed and made available in public domain
- Seasonal zonation of hilsa fishing grounds has been done and potential fishing zone advisories for fishers were formulated

Reservoirs

Large number of reservoirs have been commissioned in India in post-independence era, with primary objective of storing river water for irrigation and power generation. These water bodies hold tremendous fisheries development potential. The sheer magnitude of the resource makes it possible to enable substantial increase in production by even a modest improvement in yield. The Ministry of Agriculture, Government of India classified reservoirs as small (<1000 ha), medium (1,000 to 5,000 ha) and large (>5000 ha) for the purpose of fishery management. Medium and large reservoirs are fewer in number, while large number of small reservoirs are common for most of the Indian states. They exhibit wide variations in their morphometric, limno-chemical and biological characteristics making it difficult to develop to a technology package that can be adopted uniformly. Nevertheless, the research conducted by CIFRI has resulted in many guidelines, based on which the reservoir fishery managers can develop location – specific management norms. Such guidelines are more effective for the small reservoirs where the relationship between management and yield improvement is known to be more precise as compared to large impoundments. These findings got place in the National Fisheries Development Board (NFDB) and implemented Reservoir Fisheries Development Programme. The reservoirs encompassing 21 states have been stocked with fish seed and adopted *in situ* fish seed (fingerling) production technology. As a result the average fish production from this potential resource increased from 20 to 110 kg/ha in the adopted reservoirs during last five years.

The reservoir research and development achievements of CIFRI during XI Five Year Plan are mentioned below.

- Culture-based fisheries practices developed by CIFRI for small reservoirs enhanced fish yield in Karnataka, Tamil Nadu, Uttar Pradesh and Madhya Pradesh from 52 to 300 kg/ha/year at a unit cost of Rs. 8.2/kg across the targeted reservoirs; B/C ratio of 3.8 was achieved, involving *Catla catla, Labeo rohita, Cirrhinus mrigala* as major species for stocking
- Technology for carp seed raising in cages was standardized; 150-210 number of fish fingerlings (80-100 mm) were produced per cubic meter at a cost of Rs 0.4/fingerling with a cost benefit ratio of 2.5 to 2.7. Pilot scale studies showed that about 30 to 40% of fish seed required for stocking could be raised through cage culture in reservoirs
- Assessment of the impact of fish seed stocking in reservoirs in 20 states indicated significant increase in productivity to the tune of 11% (Punjab) to

88.9% (DVC reservoirs, Jharkhand) as compared to the pre-stocking productivity

- Developed a trophic model for sustainable fisheries management of reservoirs, describing the food web interactions
- Development of mass balance model through estimates of biomass, production/biomass, consumption /biomass
- Establishment of population dynamics model for the reservoir fisheries

The Wetlands

Floodplain wetlands, locally known as *jheels, beels, chaur, mauns, diyara* and *pats* represent lucrative areas for fisheries in the states of Uttar Pradesh, Bihar, West Bengal, Assam, Manipur, Tripura and Arunachal Pradesh. The floodplain wetlands have an expanse of over 3.54 lakh ha in above-mentioned states. These are shallow, nutrient rich water bodies formed due to changes in river courses from time to time. Apart from these, estuarine wetlands *(bheries)* in West Bengal covering an area of about 39,600 ha are recognized as sewage–fed aquaculture systems. The floodplain wetlands are primarily stagnant waters with and without any connection with main river. The fishery practices adopted in these waters are more near to aquaculture. The major production problems faced by the fishers were non-availability of quality fish seed, low water levels, siltation, encroachment of lake area for other uses, weed infestation, river connectivity, poor fish production technological support and poor fisheries asset structure. The institutional problems faced by the fishers were inappropriate leasing policy; the poor co-operative spirit, marketing and transport support mechanisms.

CIFRI has developed fisheries management norms for the wetlands based on fisheries enhancements. These practices have increased the fish yield of these waters manifold. Further, the pen culture technology for fish seed production has been highly successful and was made mandatory in Assam to have the lease and financial assistance.

The recent research achievements of the institute in these waters are:

- Development of management norms based on carrying capacity, ecosystem processes and natural food chain and estimation of sustainable yields of wild fish stocks to prevent their overexploitation and increase fish productivity in the states of Assam, West Bengal and Bihar through fisheries enhancements
- Standardized stocking density of major carp to maintain balanced population of endemic population and stocked fishes in wetlands
- The contribution of wild fish stocks in fishers' livelihoods in wetlands indicated Rs. 15,000 to 39,000 for wild fish stocks compared to Rs.14,000-18,000 from stocked fishes (Major carps)
- Culture-based fisheries in wetlands in West Bengal, Assam and Bihar demonstrated enhanced fish yield from 100-400 kg/ha/year to 900-1400 kg/ha/year
- Successfully demonstrated 'fish based integrated production system approach with community participation' in seasonally flooded water bodies of West Bengal and Assam, where the fish productivity could be increased from 1.5 t/ha to 3.8 t/ha with B:C ratio at 2.27
- Tested the suitability and advantages of circular pen in terms of capital cost and fish yield and better resistance for HDPE nets and ropes in pens against weather and predators
- Demonstrated enclosure culture (pens and cages) in selected wetlands of Assam and West Bengal under public-private partnership mode for greater adoptability. Cost benefit ratio was estimated at 1.3 to 1.5
- Assessed the role of macrophytes in nutrient recycling and growth of fish food organisms
- Ground truthing of wetlands in Assam
- Identification of river connectivity, aquatic macrophyte type and supplementary stocking as most critical factors for fish yield and fish species diversity in wetlands
- Survey of 164 *beels* in Assam revealed fish seed stocking only in 36% of *beels* with stocking density ranging from 833-7500 fingerling/ha
- Socio-economic evaluation of different management regimes in *beels* of Assam revealed that private regime as the best with highest fish yield and B:C ratio

Fishery environment

As mentioned earlier, the mandated waters of CIFRI for research are primarily natural with multiple uses. Therefore, monitoring environmental changes *vis-à-vis* fisheries in these waters is one of the major activities of the institute. The important information generated on most of the river systems in India is correlated with decline in fish stocks and overall ecosystem productivity. The key water quality parameters impacting the fishes at gross morphological and physiological level were investigated to develop site-specific mitigation action plan to restore and conserve our fish stocks.

The major achievements of the above in recent years are:

- Protocols for rapid and long-term 'Environment Impact Assessment' for inland open waters have been developed and standardized and trial tested
- Detailed data sets on the status of pollution, including heavy metals and pesticides have been generated and their impact on biotic communities and fisheries was documented from five rivers (Ganga, Yamuna, Brahmani, Damodar and Churni)
- Six bacterial strains, capable of releasing phosphorus from calcium bound phosphate, were isolated from wetland sediments
- 17 phenol and its derivatives like chlorophenol degrading bacteria were isolated from Churni, Hooghly and Damodar rivers. Seven of these isolates are highly capable of degrading di-, tri- and penta-chlorophenol. These bacteria have potential for amelioration of phenol pollutants
- Four bacterial strains having arsenic reduction capability were isolated from sediment samples of arsenic affected regions in West Bengal
- 79 salt tolerant bacteria were isolated and identified and 16S rDNA gene sequences submitted to NCBI Gene Bank and accession numbers accorded
- Nutrient profiling of *Tenualosa ilisha, Sperata seenghala, Puntius sophore* and *Amblypharyngodon mola* completed
- Generated proteome maps for different tissue proteins of *Labeo rohita, Sperata seenghala* and *Rita rita* to identify biomarkers suitable for aquatic pollution monitoring
- Impact assessment of climate change on inland fisheries by analyzing rainfall, and temperature data of 30 years and fish diversity in river Ganga and its plains revealed a perceptible geographic shift of warm water fishes, *Glossogobius giuris Puntius ticto, Xenentodon cancila, Mystus vittatua* and *Catla catla* to the colder stretches of river in Uttarakhand region
- Positive impact of enhanced temperature and alteration of rainfall pattern on spawning of Indian Major Carps has been recorded in their breeding pattern in hatcheries in West Bengal and Orissa evident from early maturation and advancement of breeding period in the last two decades. An extended breeding period by 45-60 days with breeding season extending from 110-120 to 160-170 days
- A method for calculating the Vulnerability Index to climate change adaptation for the inland fisheries sector has been developed for West Bengal, showing inland fisheries in 8 districts out of 17 studied are vulnerable to climate change. These eight districts need priority in fisheries planning strategy for coping with climate change

Resources assessment and database

The information on the inland fisheries waters and their fish catch is varying according to different sources and considered one of the major constraints for proper planning and policy making for development of their fisheries. The institute has separate research programme on assessment of resources and database development in GIS platform. The accomplishments of the programme during XI Five Year Plan are mentioned below.

- Developed and standardised a methodology for estimating water spread area of inland fisheries resources and their production status using GIS tools for West Bengal and Uttar Pradesh
- Mapping of open water bodies in Punjab, Haryana, Tamil Nadu, Andhra Pradesh and Chhattisgarh has been completed using GIS tools for their proper delineation
- Preparation of electronic atlas for water bodies of >10 ha area in 6 States (Kerala, Karnataka, Maharashtra, West Bengal, Punjab, Haryana, Bihar) has been completed. These atlases can be web based and used as a ready reference tool, both online and offline
- Digital Elevation Model of catchments and streams were created for four water bodies of West Bengal and six water bodies of Uttar Pradesh

Socio-economic assessment and resource valuation

The fishers operating in inland open waters are recognized as one of the poorest community in the society. They are highly unorganized and hardly get the appropriate remunerations for their catch. They are the ultimate clientele of CIFRI R&D efforts. Keeping these facts in mind, it is pertinent to investigate socio-economic conditions of the fisher community. All the inland waters have multiple uses, and fisheries is considered as a tertiary activity. Therefore, to establish fisheries as one of the major livelihood generating activity, it is necessary to document all the goods and services provided by these aquatic ecosystems. CIFRI has initiated the valuation exercise of inland open waters. The outputs of these activities are as under

- Documented the literacy, income and health status of inland fishers in the country. It indicated comparatively poor condition of the community for all above parameters
- Assessment of the socio-economic conditions of fishers of Ganga river system
- Developed methodology for valuation of inland open waters with emphasis on fisheries
- The valuation of goods and services of two wetlands and one reservoir in West Bengal established fisheries as the most important activity in wetlands (> 50% contribution of total value) and second best activity (6% share in total value) in reservoir after irrigation
- Valuation of the goods and services provided by a seasonally flooded area in West Bengal also confirmed fish as the major component of its value (74%), followed by ground water recharge/ irrigation (20%), and conservation of habitat for aquatic biomass, aesthetics, etc. formed 6% of the total value

Strategies for XII plan

Based on the experiences of XI and earlier plans, CIFRI formulated the following strategy for future fisheries research and development in inland open waters.

Conservation of biodiversity in inland open waters

- Evaluation of present status of biodiversity in inland open waters in a network mode with other organizations
- Identifying the threat perceptions for loss in fish biodiversity for formulating conservation plans
- Providing necessary inputs for developing policy guidelines to create sanctuaries, deep pools and other protected habitats to conserve fish germplasm in rivers

Impact assessment of hydrological changes in relation to fisheries

- Hydrography and fish behaviour in relation to hydraulics in various riverine systems
- Designing of proper fish passes/ladders in dams and barrages to ensure migration of fish
- Determining the requirement of minimum environmental flow for the sustenance of ecosystem integrity, including biodiversity and fish stocks

Environmental impact assessment and ecosystem health

- Monitoring heavy metal and pesticides residues in inland open-waters, down the food chain for developing mitigation plans
- Developing bio-monitoring protocols for rapid survey of stressed ecosystems
- Developing bio-manipulation techniques to improve ecosystem health and fish stocks

Formulation of management plans for fisheries in rivers and estuaries

- Evaluating the current status of ecology, fishery and biodiversity of various rivers and estuaries of the country in phased manner
- Evaluating the status of mangrove wetlands in relation to various threat perceptions and their impact on ecology and fisheries
- Identifying the existing and emerging threat perceptions in riverine and estuarine fisheries for developing a suitable action plan for responsible fisheries
- Time scale investigations on watershed, discharges, salinity dynamics, sedimentation pattern, nutrient dynamics, production status and fisheries of various rivers and estuaries including their floodplains
- Management plans for responsible fisheries

Fisheries enhancement and management of reservoirs and floodplain wetlands

- Developing location-specific fisheries management norms for medium and large reservoirs/ wetlands in accordance with:
- Production functions
- Food chain status
- Nutrient status
- Manipulation of stocks and fishing efforts.
- Developing protocols for various modes of fisheries enhancements in small reservoirs/wetlands

- Stock enhancement
- Species enhancement
- Environment enhancement
- Pilot-scale testing of various enhancement tools in reservoir & floodplain wetlands for sustainable yield

Increasing fish production per unit area in reservoirs and wetlands through enclosure culture

- Extension of pen-culture technology in reservoirs and floodplain wetlands, located in different agro-climatic conditions, for raising table fish and stocking materials
- Production of table size fish/prawn in enclosures (pens) for higher yield and better economic return from wetlands
- Raising of stocking materials (advanced fingerlings) in pens installed in wetlands
- Extension of cage culture technology in reservoirs and wetlands for
- Raising quality fish seeds for stocking in reservoirs and deeper wetlands for yield optimization and sustainable fishery
- Standardization of cage culture technology for producing high value table fish
- Evaluating environmental impact of commercial cage and pen culture in relation to ecology and fish production of the systems

Application of biotechnology in aquatic environmental management

- Development of genomic and proteomic biomarkers for aquatic environment assessment
- Development of microbial bioremediation techniques for environmental amelioration
- Genetic characterization of fish stocks for sustainable fisheries management in inland open waters

Resource assessment and development of predictive models for inland open water fisheries

- Assessment of varied inland fishery resources in the country using remote sensing techniques
- Investigating population dynamics of important fishery for determining the MSY levels for commercial fish species of rivers and estuaries to develop a predictive model of optimum harvesting of fish stocks on sustainable basis
- Developing predictive models for assessing fishery potential of various inland open waters

Mining of already available data & generation of additional database on inland fisheries

- Revisiting the available databank at CIFRI for formulating suitable guidelines for fisheries development and conservation of fish stocks in open-waters, rivers, estuaries, reservoirs and wetlands
- Standardizing and up-scaling the sampling methodologies for generating reliable database
- Digitizing the database and other research contributions on GIS format for better management
- Synergizing all efforts for achieving sustainable fishery through effective linkages with all stakeholders
- Preparing time-series biodiversity inventories of fish, plankton, macrophytes, benthos and microbes in collaboration with other related institutions to keep a track on natural food chain
- Generating basic data on various aspects of climate change and its impact on biodiversity and fisheries

Water and nutrient management for sustainable inland open water fisheries

- Assessing the requirement of water for dominant fish species at different life history stages in open waters
- Estimation of environmental flows and water volume for the sustenance of desirable fish stock in rivers and estuaries
- Nutrient dynamics in reservoirs, wetlands riverine ecosystems

Environmental economics and resource valuation

- Appraisal of role of socio-institutional settings and community-resource interactions towards use and sustainability of natural resources

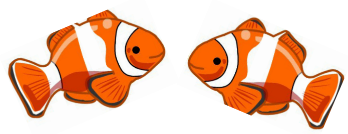
- To document the goods and services provided by the inland open water resources and develop methodology for their valuation

Evaluation of socio-economic status of open water fishers and their active participation in resource management

- Socio-economic appraisal of fishers operating in open-water ecosystems to understand their economic status and to suggest alternative livelihood
- To develop protocols for community based fishery exploitation and other services from the ecosystems

Sensitization of stakeholders on various aspects of environment and conservation

- All the stakeholders operating in open waters will be sensitized about the negative impacts of environmental perturbations and irresponsible fishing practices
- Necessary efforts will be made to educate the stakeholders on the importance of conserving fish stocks
- Required literature, film clippings and other electronic support will be developed in regional language to create awareness among common people



W. S. Lakra

Application of biotechnology in fish genetics and health management

W.S. Lakra and K. V. Rajendran
Central Institute of Fisheries Education
Versova, Andheri (W), Mumbai- 400 061

The term biotechnology, according to the Convention on Biological Diversity, is defined as "any technological application that uses biological systems, living organism, or derivatives thereof, to make or modify products or processes for specific use". In the context of aquaculture, Liao and Chao (1997) have described biotechnology as the scientific application of biological concepts that enhance the productivity and economic viability of its various industrial sectors. In fisheries and aquaculture, biotechnology has wide range of applications such as improving the growth and disease resistance of cultured organisms through genetic manipulations and other means, developing feeds with improved nutritional value, improving aquatic animal health management through sensitive early diagnostics, vaccines and therapeutics, helping to restore and protect aquatic environment, developing better post-harvest technologies and value-added commodities from fish and fishery products, improved management and conservation of aquatic resources. Accordingly, application of biotechnology has been contributing to the increased production through aquaculture. However, compared to agriculture and terrestrial animal production sectors, potential of the application of biotechnology has been less realized in this sector. This is exemplified by the fact that the application of genetic principles to increase production from aquatic animals lags far behind that of the plant and livestock sectors.

Although aquaculture production has increased 60-fold during the past 60 years, production of many aquatic species still depends on wild-caught broodstock or seeds. According to Gjedrem (2005) less than 5% of production was estimated to come from scientifically managed breeding programmes. However, aquatic species have many advantages for genetic gain such as external fertilization and high fecundity, allowing a large number of gametes to be collected and fertilized under controlled conditions. Further, better estimate of genetic parameters is possible in aquatic species because breeding designs with large family sizes can be constructed. The genetic improvement thus obtained can be transferred quickly to industry. The genetic improvement programmes have been focusing on many attributes of the cultured species, however, emphasis has been given on growth, maturation, disease resistance and environmental tolerance.

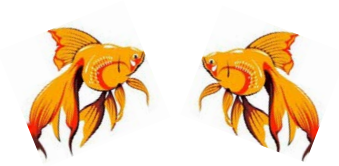
A wide range of biotechnological tools have been employed in the area of fish genetics. Utilizing the advantage of ease in the collection of gametes, inter-specific and inter-generic hybridization have been successfully employed to generate hybrids in aquaculture. Successful selective breeding programmes for desirable traits have been reported for many species of fish such as common crap, rainbow trout, Atlantic salmon, tilapia, channel catfish and ornamental fishes. Further, improved resistance in Atlantic salmon to viruses has been achieved through the application of genome technologies including quantitative trait loci (QTL) and marker-assisted selection (MAS) approaches. Chromosome set manipulation through environmental alterations to generate triploids is another example of successful application of these tools in the area of fish genetics. Protocols for achieving triploid condition are available for more than 30 different species of fish and shellfish. These triploids have potential in improving growth, flesh quality and reducing the risk of inter-breeding of farmed escapees or exotics with the native populations. Triploid sterility can also be applied to prevent the impact from escaped transgenic fish.

Gene transfer technology to produce transgenic fish have been a very interesting topic because of its immense potential apart from many technical/practical constraints and the issues related to public acceptability and environmental risk. Due to the constraints and the potential social and environmental implications, it has been suggested that transgenic fish are unlikely to become a commercial reality in the immediate future. However, transgenic fishes with human growth hormone gene as well as piscine constructs and antifreeze protein (AFP) genes have been produced. In the case of salmon, even though little is known about the potential impact of genetically modified escapee to the wild population, salmon produced using growth enhancing transgenic technologies is one of the species considered for commercial farming. Further, genomic research is progressing in many parts of the world to identify candidate transgenic genes especially responsible for improved disease resistance.

DNA-based genetic markers play a significant role in fish genetics research and the application of DNA markers has enabled a rapid progress in the area of genetic variability and inbreeding, parentage assignments, species and strain identification and the construction of high-resolution genetic linkage maps for aquaculture species. Molecular markers in aquatic organisms have been reviewed by Liu and Cordes (2004) and Liu (2009) and it has been suggested that these markers will progress the research on marker-assisted selection. Besides, it is reported that genetic markers have potential use in managing wild and farmed stocks by identifying the origin of escaped farm stock and potential introgression of genes from farm escapees into wild population. Genetic linkage map which helps to identify QTL or genome section containing genes influencing important traits has been developed for many important cultured species. Besides rapid development in identifying expressed sequence tags (EST), other areas which have been developing rapidly include research on bacterial artificial chromosome (BAC) libraries and single nucleotide polymorphism (SNP) in many aquaculture species. In the area of functional genomics, construction of microarray chips containing thousands of ESTs have been progressing in studying gene expression for different traits particularly disease resistance. Further, new generation sequencing technologies, including RNA-Seq is going to play significant role in the field of fish genetics. However, despite the tremendous progress achieved in the field of fish genetics research on many cultivable aquatic species in other parts of the world, application of biotechnology to improve the production traits of cultured fishes in India is lagging behind. One of the challenges the Indian researchers in this field should address is how to generate high quality genomic resources for the indigenous fish species in a short span of time. However, with the improved infrastructure and the resources available to the fisheries research it is possible to generate this database and utilize the resources for improved and sustainable aquaculture production.

Similarly, biotechnology has a wide-range of applications in aquatic animal health management. According to Adams and Thompson (2006) biotechnology can have a direct positive impact on many of the main elements of fish health management, with knock-on effects to other important issues. Through biotechnological application, major progress has been achieved in the field of aquatic animal disease diagnosis. This is significant, as the rapid, sensitive and early diagnosis of diseases in aquaculture could contribute not only to the effective health management strategy but also help to reduced application of antibiotics and chemicals in the environment. This also helps in screening the pathogens and develops certification capability to restrict the trans-boundary movement of pathogens through the import/export of aquatic animals/products. Another area which has been benefited through biotechnology is the development of vaccines for aquatic pathogens and there have been significant contributions during the past several years in this field. Similarly, development of cell culture system from aquatic species has been complementing recombinant DNA technology in the application of biotechnology to aquaculture.

The genomics and proteomics, alone or in combination with each other or with other conventional methods, have been contributing to the understanding of diseases in higher vertebrates and were responsible for developing diagnostics, therapeutics and vaccines. Concomitant with this development, the technologies are increasingly being used to support similar research in the area of aquatic animal health. This transformation is reflected in the fact that there are many commercial diagnostics and vaccines available for aquatic animal diseases and many R&D programmes on developing high throughput diagnostics for important pathogens of aquaculture species. Substantial reduction in the cost of many technologies such as sequencing also contributed to the tremendous progress in aquatic animal health research both in basic and applied areas. Although sequence information of pathogens is increasingly being available, there is a lack of similar information on the host organisms. However, there has been an increased focus on identifying and characterizing new genes involved in host immunity and elucidating their roles. Although application of biotechnological tools have greatly enhanced our knowledge and understanding about many pathogens to a great extent, one of the challenges the aquatic animal health researchers face is how to interpret these information in the context of a disease process and host-pathogen interaction. Further, as pointed out by Johnson and Brown (2011) the ability to generate large and complex data sets on both pathogens and hosts would create new set of problems to the fish health research community in the areas of data management, analysis (bioinformatics and statistics), storage and archiving. However, a platform, on which geneticists and aquatic animal health specialists can collaborate and coordinate their efforts, would help to harness the potential of bioinformatics and to utilize the genomic resources in an efficient way.



Freshwater aquaculture in India current status and prospects

P. Jayasankar
Central Institute of Freshwater Aquaculture
Kausalyaganga, Bubaneswar 751 002., *E-mail.pjayasankar@yahoo.com*

Introduction

Population growth, increasing affluence and changing dietary habits have led to rapid rise in global demand for food, and a report of FAO (2009) forecasts the need to increase food production by over 40% by 2030 and over 70% by 2050. Fish as the cheapest source of animal protein constitutes a major share in the global food basket and world fish production sector faces the challenge to boost the production to meet the protein hunger in the future. According to latest statistics, global fish production stands at 147.5 million tonnes, of which about 40% is contributed by aquaculture sector. However, global capture fishery being at crossroads with over 70% of the resources exploited, aquaculture is the only option to fill up the gap of much of the future fish demand.

Indian fisheries sector has made great strides in the last five decades showing eleven fold increase, from 0.75 million tonnes in 1950-51 to 8.1 million tonnes in 2009-2010,which is a testimony to the contributions of the sector. The share of inland fisheries sector, which was 29% in 1950-51, has gone up to over 61% at present. Besides providing livelihood security to over 14 million people, the sector has been one of the major foreign exchange earners, with revenue reaching Rs. 10,048 crores in 2010-11 accounting for about 18% of the agricultural export. Producing 5.42% of the world's fish, India trades to the extent of 2.5% in the global fish market. Fisheries sector has registered an overall annual growth rate of 4.5%. During the previous five year plans contribution of fisheries sector is estimated around 1.10% to the GDP and 5.3% to the agricultural GDP (Ayyappan *et al.*, 2011), thus boosting the agricultural growth since last several years. Capture fishery in the country being almost stagnant since last three decades, freshwater sector has been shouldering the major responsibility to meet the increased demand for fish (Fig. 1).

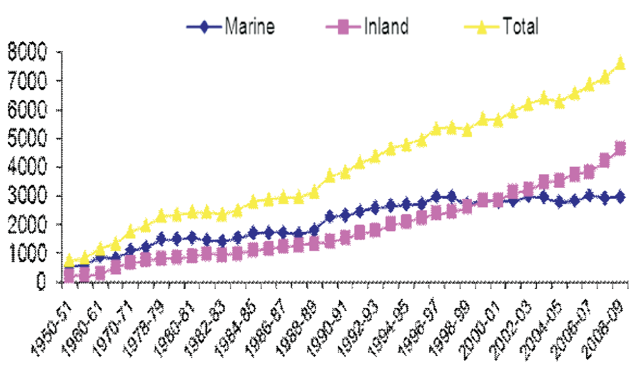


Fig.1. Trends in marine and inland fish production in India

Growth of freshwater aquaculture

Freshwater aquaculture which began as small scale activity of stocking ponds with fish seed collected from riverine sources during early fifties in rural Bengal and continued as a subsidiary farming activity serving only a family's daily needs even till eighties, has now transformed into a major economic activity assuming the status of an industry. With rich resources in terms of water spread as well fish/shellfish species, the aquaculture sector is being recognized as one of the most economic farming practices and is receiving increasing investments. Aquaculture accounts for about half of the total fish production and provides food and nutritional security to millions of people at affordable price as well as contributes to the livelihood support to a large number of rural populations in the country. Its growth rate (over 6% a year) is the fastest among all other food production systems. It is also considered as the most efficient form of animal production system.

India, as the second largest aquaculture producer in the world (first being China), has the major contribution from freshwater aquaculture, whose share in inland fisheries has gone up from 46% in the 1980s to over 80% in the recent years. The sector, during the past two decades, has shown an overwhelming ten-fold growth from 0.37 million tonnes in 1980 to 4.03 million tonnes in 2010. Freshwater aquaculture has been able to meet the increasing fish requirement of the country when the production from marine capture and other open waters has remained almost stagnant (Ayyappan *et al.,* 2011). It is estimated that only about 40% of the available area of 2.25 million ha of ponds and tanks, 1.3 million ha of beels and derelict waters and 2.3 million ha of paddy fields has been put to use and there exists amble scope for horizontal expansion.

The freshwater aquaculture practices are highly eco-sustainable, being compatible with other farming systems. Carps, Catfish, prawns and molluscs, the last with reference to pearl culture, provide for the requisite diversification in the practices as also utilization of organic wastes and wastewaters, even serving the needs of treatment. There has been a spurt in the freshwater aquaculture activity in the country, as seen in the Kolleru lake basin of Andhra Pradesh and even in non-traditional aquaculture states like Punjab, Maharashtra, and Gujarat. With the resources and technologies available, great emphasis is being laid on technology transfer to achieve "Blue Revolution" in the sector, and the present production level will be targeted to rise in a sustainable manner to about 10.0 million tonnes by 2030 applying holistic principles in tune with the increasing per capita availability.

Freshwater aquaculture sector provides direct or indirect employment to about 5 million people of the country. About 1.3 % of the landowning households are reported to be involved in the aquaculture activities and estimated 1.1 million farming households are involved in aquaculture. Aquaculture generates income and employment opportunities across the chain of seed production, fish culture, fish harvesting, input supply, trading, marketing as well as processing. Globally, aquaculture is being seen as antidote to fight poverty and malnutrition. Many developmental programmes like MGNREGS, watershed development etc. consider aquaculture as a means to enhance the overall impact on the poverty alleviation in rural areas.

Seed production scenario

Seed is the most critical factor for aquaculture development in the country. The blue revolution started with the development of seed production technology through induced breeding (hypophysation) by the erstwhile Pond Culture Division of Central Inland Fisheries Research Institute (presently Central Institute of Freshwater Aquaculture, CIFA) during late fifties. (Fig. 2)

Sequel of activities at CIFA as well as other parts of the country, including ampouling of pituitary extract, refinement of breeding protocol, evolution of an array of hatchery technologies and hatchery models from the initial earthen pits to the latest circular eco-hatchery model and portable FRP hatchery (Fig. 3) have provided scope to produce seed in mass scale. The once highly skill demanding induced breeding technology has been popularized as a more user friendly one which helped it spread across the length and breadth of the country. The easy availability of synthetic hormone formulations further has given fillip to the seed production. At present, more than 1100 fish hatcheries are operating in the country in both public and private sectors. Total carp fry production increased from 409 million during 1973-74 to 32,254 million in 2009-10 making the country self-sufficient in the fry production of carp. CIFA is also credited with development of technique for advancing and delaying of the breeding season of carps ensuring expanded breeding season and round the year availability of right kind of seed.

CIFA took further lead in broadening the scope of hatchery seed production and brought into its orbit the medium sized carps, air-breathing and non-air-breathing Catfishes, murrels, freshwater prawn, etc. to meet the growing seed requirements and diversification of aquaculture, making it more rewarding. Presently, more than 35 prawn hatcheries are established in the coastal states of the country producing 200 million postlarvae. While some Catfish hatcheries are operating in commercial scales, many states have initiated the activity on pilot scale which is likely to expand in future. Breeding and seed production techniques of the regionally important species are now available opening scope for diversification of aquaculture.

Despite the self-sufficiency in the fry production, availability of fingerlings for grow-out culture is yet inadequate in the country mainly due to non-availability of rearing space and lack of entrepreneurship for seed production. However, continuous effort by the

Fig. 2. Farm facilities at CIFA

Fig. 3. FRP carp hatchery

government organization, research institutes and private sectors over the years and in future are expected to increase the fingerling availability. Production of stunted fingerling in recent years has become important technology for round the year seed availability.

Grow-out fish production

Over the years, freshwater aquaculture in the country has witnessed development of specific and widely adaptable culture systems with regard to type of water bodies, culture period, inputs use and with due consideration to the availability of local resources, economic strength of the farmers and market acceptability of the produce. Polyculture of Indian major carps alone or along with exotic carp at lower to moderate stocking density has been realising the production of 4-10 tonnes/ ha/yr. But there are wide variations across the states and production environments. The commercial farmers of Andhra Pradesh and Punjab have achieved more than 6 t/ha/yr whereas it was less than 1 t/ha/yr in case of the community aquaculture. The research farms of CIFA have demonstrated production as high as 17 t/ ha/yr. However, the average aquaculture production in the country remains 2-3 t/ha/yr. It underlines that actual production is quite low and a wide yield gap exists which can be bridged through the development of different disciplines under the umbrella of freshwater aquaculture accompanied by aggressive dissemination.

Production growth can also be achieved through horizontal expansion of the culture area, improvements in the productivity of the culture system by efficient input use, genetic improvement, effective husbandry, health management, etc. In future, aquaculture will be more technology and input based with greater intensification per unit water bodies to produce more fish per unit area. In this context setting up of more fish feed production units at suitable locations along with mapping the potential agro-based feed ingredient availability in various zones of the country and a database on their nutritive values and nutrient digestibility would be a major step ahead.

Fish feed

Feed constitutes about 60% of the production cost in commercial aquaculture. At present, only 43.85 million tonnes of concentrate feeds are available in the country, where as the demand for concentrate feeds by the different animal husbandry sectors is 142.68 million tonnes, with a huge deficit of 69.3%. The aquaculture sector currently uses about 20% of total available concentrate feeds in the country and by the year 2030, about 12-16 million tonnes of feed would be required to sustain a freshwater fish production target of 8.0 million tonnes per annum.

At present, about 8 million tonnes of feed is used by the aquaculture industry in the country with a feed conversion ratio (FCR) of 3.0 in carp culture. FCR as low as 1.7-1.8 was achieved during feed demonstration in the farmers' ponds by CIFA. Fish meal and fish oil are completely replaced by plant ingredients in the diets of IMCs without affecting most wanted nutrients such as Eicosa Pentaenoic Acid (EPA) and Docosa Hexaenoic Acid (DHA) in fish flesh. Newer non-conventional fish feed ingredients are identified, evaluated and incorporated in feed formulations. With long research experience in fish nutrition and feeding, CIFA has developed weaning feeds "Starter-M" for magur, and "Starter Pangas" for *Pangasius sp*. The grow-out feed "CIFACA" and brood fish feed "CIFABROOD" have been developed for carps. Also, "CIFAPRA" is developed as an ideal feed for *Macrobrachium rosenbergii.*

Health Management

Health management would play a pivotal role in the coming years for sustainability of semi-intensive or intensive systems of aquaculture. The misuse and drawbacks in antibiotics, problems of emerging pathogens, transboundary diseases, poor quarantine etc. are further adding up to this issues for moving into better health management practices. To meet the challenges of newer and emerging pathogens, there is a need to emphasize on the development of newer molecular-based, specific, sensitive and farmer-friendly disease diagnostics. Exploration of immune system of major cultured candidate species and understanding pathogenesis of important diseases would pave the way in developing suitable immunoprophylaxis is using latest molecular approaches. Frontier research on immune related genes to identify host-pathogen interactions, and application of nanotechnology in disease diagnostics and vaccine development and water remediation are the priority areas. Diseases like argulosis, edwardsiellosis etc. that pose major threats to the industry would be given priority using novel approaches of prevention or control.

Preparation of the therapeutic formulation 'CIFAX' to curb the dreaded ulcerative disease syndrome and many other therapeutics and diagnostics developed from time to time describe CIFA's excellence to act as a watch dog against the risk of upcoming diseases and fish health problem.

Climate change and aquaculture

Temperature rise is the major effect of global warming and the effects are likely to continue in the foreseeable future. The Inter-Governmental panel for climate change (IPCC) report indicated that many of the developing countries tend to be vulnerable to extreme climate disturbances and thus may have an adverse impact of a gradual climate change on animal production system including fish farming through aquaculture. Fish, being poikilothermic in nature, are prone to physiological changes pertaining to global warming. Given the importance of climate in the aquaculture production system, it is essential that concerted research efforts be carried out to assess the vulnerability of aquaculture towards the impact of climate change, prioritize the strategies and also to identify the stakeholders' response.

Global warming is likely to create favourable climate conditions for the growth of causative organisms and thus increased ambient water temperature is likely to cause a rise in the responses of disease occurrences spread by vectors. Similarly alterations in water quality parameters such as ammonia, air and water temperature may have pronounced effect on feed utilization efficiency, growth and even on the sensory qualities of the cultured fish species. Concerted efforts in aquaculture research to reduce the vulnerability of aquaculture due to the impact of climate change are therefore vital to make aquaculture more resilient.

Species diversification

Realizing the need for diversification in aquaculture in the country, CIFA has undertaken timely intervention in developing the technology for domestication, captive propagation and culture of many important species including minor carps, medium sized carps, barbs, Catfish, murrels, freshwater prawn, pabda, climbing perch, freshwater pearl mussel, etc. either in monoculture or polyculture with the conventional major carps. Efforts are also on to bring new species from the rich fish diversity of natural waters to broaden the species spectrum (Fig. 4). Apart from promoting the established ornamental fish species, attempts are made to develop the breeding and production technology package for propagation of the indigenous fishes of ornamental value. The Institute has initiated studies on the small indigenous species (SIS) for the nutritional security especially for the rural poor and also for effective utilization of the seasonal ponds.

Fig. 4. Haul of diversified fish

Carps

Carp culture in India, during the last five decades, has grown in geographical coverage with diverse systems, besides intensification of farming practices. The researches over the years have led to the development, refinement and standardization of a host of technologies with varied production levels depending on the input use, incorporating the Indian and Chinese carps. In addition to Indian major carps (*Catla catla, Labeo rohita* and *Cirrhinus mrigala)*, the country possesses several other potential and cultivable medium and minor carp species having a high regional demand, *viz., Labeo calbasu, L. fimbriatus, L. gonius, L. dussumieri, L. bata, Cirrhinus cirrhosa, C. reba, Puntius sarana* and *P. jerdoni*. Presently, efforts are being made for mass-scale seed production of these species and their inclusion as a component of conventional carp polyculture, based on their regional importance.

Catfishes

Air breathing Catfishes, *Clarias batrachus* (magur) and *Heteropneustes fossilis* (sisnghi) could be grown in swamps and have a high consumer preference. However, in spite of the availability of resources in the form of swamps and derelict waters which could be effectively used for commercial farming, their large scale seed production and culture have not taken place.

Non-air breathing Catfishes such as *Pangasius pangasius, Sperata seenghala* and *Ompok pabda* are potential species for diversification in the coming years. Further, climbing perch *(Anabas testudineus)* and murrels *(Channa striatus* and *C. marulius)* are being considered for culture.

The constraints in propagating these fishes are with regard to availability of seed in adequate quantities and special feed formulations to suit the diet of carnivorous fishes needing incorporation of fishmeal.

The exotic striped Catfish *Pangasianodon hypophthalmus* was first introduced into India in the year 1995-96 in the state of West Bengal from Thailand through Bangladesh. Initially farming was carried in limited area in the states of West Bengal and Andhra Pradesh. But since 2004 its farming has increased due to the commercial importance and by 2008 it is estimated that *Pangasius* is being farmed in an area of about 40,000 ha with an expected production of 1.80 to 2.20 lakhs tons. There is a growing interest among the farming community in other states as well to take up *Pangasius* culture in a larger extent, thus paving way for demand for its seed and for establishment of commercial scale hatcheries. *Pangasius* is being farmed under monoculture or polyculture with carps. In Andhra Pradesh a total of 12,000 ha are under striped catfish culture at present. With an average production of 17 t/ha/year the total annual production of this species in AP stands at 2 lakh tonnes. There is only a single hatchery for *P. hypophthalmus* in the state and depends heavily on the seed from West Bengal, most of which might be coming from Bangladesh.

Freshwater prawn

Freshwater prawn farming has received increased attention only in the last two decades due to its demand. The giant freshwater prawn, *Macrobrachium rosenbergii* (also known as scampi), the largest and fastest growing prawn species, is cultured either under monoculture or polyculture with major carps.The country produces over 30,000 tonnes of freshwater prawn annually from a cultivated area of 43,433 ha with a mean productivity of 990 kg/ha/yr (Ayyappan *et al.,* 2001).

Andhra Pradesh has been the lead producer with 87% of the total production. Seed production has been adequately addressed through hatcheries not only in the coastal states, as larval rearing requires an amount of salinity, but also demonstrated in inland states using artificial sea water or ground saline water. Due to slump in overseas market for *M. rosenbergiiin* the last two years horizontal expansion of scampi has taken place (Fig. 5). Poor and heterogeneous growth and white tail disease have been the other problems in its cultivation. However, polyculture with carps has become remunerative, again requiring establishing domestic market models. At CIFA a research project on the selective breeding of scampi has focussed on improved growth rate.

Fig. 5. Haul of cultured freshwater prawn *M. rosenbergii*

Diversification of production system

Increasing demand for fish has necessitated need based modification and improvement of the existing seasonal and perennial production systems. In addition to the improvement in the conventional carp based production system, many diversified systems have been developed including feed based system, periphyton based system, organic farming, use of stunted stocking materials in production system, low and high input based system, fish based integrated system, waste water system, cage culture, etc.

Concepts like biofloc technology, cropping cycle, intercropping with compatible species, high end aquaculture with use of oxygen injection, supply of enriched diet, automatic feeder, farm automation etc. have been introduced in the aquaculture system to increase the carrying capacity and fish production within the system. Some of these systems have not only proven advantageous in terms of production increase, but also have ensured better resource utilization and ecofriendly protein production. However, in order to meet the future demand of fish in the country, all these processes need to be operated at more efficient level which warrants refinement, modification and further improvement in the production systems.

Waste water recycling and reuse in aquaculture

With increased industrialization and urbanization, India is approaching a regime of water stress in the foreseeable future. With this, there has been gradual shrinkage in the share of aquaculture in the country's freshwater resources. It is not only the people who are threatened by water shortage and environmental degradation, but also freshwater ecosystems like seasonal wetlands which harbour the world's greatest concentration of species have been affected.

The increasing pressure on freshwater resources coupled with increased demand for more fish production have necessitated exploring possibility of increasing water productivity through multiple water use and recycling waste water. There is a need that a large share of water must come to meet new demands by saving water from existing uses since this will have considerable use and interest in developing countries in the tropics in realizing the water productivity on human food production, crop diversification, environmental hygiene and finally poverty alleviation programme. Fortunately, aquaculture offers opportunity for productive utilization of such waste water resources for fish protein production while ensuring the treatment of waste which otherwise would have caused environmental concern.

Pilot scale on-farm and on-station researches on the efficacies of waste water utilization in aquaculture *vis-à-vis* conventional feed-based fish production indicated promising results with added advantage of harvesting more crops per drop of waste water. Sewage-fed aquaculture which has been practiced in Kolkata since long without prior chemical or biological treatment has been playing a great role in water quality improvement. Low value water from various sources such as dairy, brewery, rice mill, food and beverage plants and silk reeling industries have been effectively incorporated in aquaculture system for fish production realizing the increased water productivity. However, with the increasing population in the country, the quantity of wastewater generated has been increasing beyond the treatment capacities, apart from host of industrial effluents and solid wastes in recent years. Intense efforts are being made at treating the domestic sewage to make the effluents suitable for discharge into the natural waters. The mechanical and chemical processes are widely used for treatment of domestic sewage; the latest one is the Up flow Anaerobic Sludge Blanket (UASB) process. The emphasis in these practices has been on the recovery of nutrients from the waste water for fish and prawn production.

Genetic and biotechnological interventions

Modern developments in genetics and biotechnology have great potential to increase food production efficiency in the context of aquaculture. Development of improved rohu, CIFA IR 1 (Jayanti) by CIFA through selective breeding, demonstrating over 17% higher growth per generation after seven generations, is considered a landmark (Fig. 6).

There has been a paradigm shift in the approach to trait associated gene identification with the advent of high throughput genomics platforms and precision bioinformatics tools. Therefore, the future of marker

Fig. 6. Jayanti rohu

assisted breeding schemes in fish would lie in the prediction of total genetic value. It has already been proved that selective breeding procedures can improve economic traits, such as growth, disease resistance etc. in fish. DNA marker based approaches have high potential to support the conventional selective breeding in augmenting genetic up gradation of cultured stocks. However, there is a need to emphasize on collaborative or consortia based research with multidisciplinary approach.

In the context of Indian aquaculture, genomic resources have started coming up along with the efforts to identify and characterize candidate genes for abiotic stresses, disease resistance and many other important economic traits from fish and prawn. Disease diagnostics and control (molecular approach, control/ prevention and alternate approaches for fish immunity) transgenics & value addition (ornamental fish), stem cell technology (embryonic and spermatogonial), reproductive biotechnology (regulation, control and gene expression), nutritional biotechnology (regulation and gene expression), microbial biotechnology (probiotics and bioremediation) and nanotechnology (nanofibre based scaffold) are expected to be dished out for aquaculture applications in the coming years.

Biosecurity aspects

Rapidly expanding global trade in aquatic animals and their products offer avenues for trans boundary spread of pathogens. Biosecurity system should be stringently implemented from the hatchery to the consumers through the rearing stages. Over the past several decades, the expansion and intensification of aquaculture production has been accompanied by increased movements of live aquatic animals and aquatic animal products, including broodstock, seed and feed. This process of expansion, along with globalization, has paved way for accidental spread of diseases into new aquatic populations and locations.

Small holders and community aquaculture

The debate over the small versus large holders for aquaculture is often inconclusive. While the large holders' commercial aquaculture in states like Andhra Pradesh or Punjab produce fish for the market, the smallholders' aquaculture is meant for the family and local consumption. Therefore, the social impact of the smallholders' aquaculture for the food and livelihood security is quite high. Over the last four decades the number of operational holdings has doubled and the average size of the farm declined from 2.63 ha to 1.06 ha, resulting in access to only small patches of water bodies (about 0.1 ha) to many. Water bodies like community ponds and leased ponds etc. are also small in the range of 1-2 ha. In future many of these small ponds operated by the small and marginal farmers will shoulder major responsibility in the aquaculture development. It has been shown that the poor in developing countries get a higher share of their much smaller animal protein consumption from fish than do better-off people in the same countries. Access to the small aquaculture resources, technology and fish with reduced price has a welfare effect of aquaculture. In this context CIFA can take the lead to teach the farmers to do the scientific farming by providing them with quality inputs and technology.

The community based aquaculture is an emerging area of the fish farming in the rural areas. There are many forms of water bodies like common property resources, small irrigation tanks, water harvesting structures, community ponds etc. being held by the collective body like panchayat, government or other public agencies. In most of the cases, these water bodies are being leased to the collective or community based organizations like cooperatives, self-help groups, youth clubs or other bodies for aquaculture. Such community aquaculture has provided significant social benefits to the community and therefore this has been promoted by many governments. The lease policy, technology transfer and Freshwater Fish Farmers Agency (FFDA) input support etc. will be required for the community aquaculture development.

Ornamental fish farming

With a rich diversity of ornamental fishes with over one hundred varieties of indigenous species, in addition to similar number of exotic species that are bred in captivity, the export potential of ornamental fishes from India is of the order of US$ 30 million (Ayyappan *et al.*, 2011). However, the export of the country at present is mainly confined to some indigenous species from north-eastern states and a few exotics with the share in Asia's exports being only about 2%. Gold fish is the most common and preferred fish because of its varied colouration and morphological characteristics.

The areas adjacent to the metros, Kolkata, Chennai and Mumbai have become major breeding centres for freshwater ornamental fishes due to ready urban market and access to export business. In recent years, breeding units have been established in states like Kerala, Andhra Pradesh, Orissa and Bihar.

Future strategy

The strategic goals for research and development to enhance fish production from freshwater aquaculture systems include: horizontal and vertical expansion of culture activities, improvement of seed production systems, system and species diversification and prioritization, genetic upgradation of prioritized cultivable species, development of feeds of prioritized cultivable species, improving water environment for aquaculture, fish and shellfish health management, water management, farm mechanization and automation, capacity building, strong extension mechanism and socio economic impact and policy research.

Epilogue

It is expected that the fish requirement by 2025 would be of the order of 16 million tonnes, of which at least 12 million tonnes would need to come from the inland sector and aquaculture is expected to provide over 10 million tonnes. In order to meet this challenge it is imperative to be pro-active and committed through adoption of the frontier research areas including development of production system for efficient use of nutrients and water, enhanced tolerance to biotic and abiotic stress imposed by climate change, achieving rapid growth rate of cultured fish following nutritional principles, development of an integrated, cost effective marker assisted breeding plan through the application of biotechnology, concerted and integrated efforts with effectiveness and efficiency to meet the ever increasing demand for fish, ensuring the code of responsible aquaculture. With the above strategy and suitable action plan in place, the aquaculture sector will be contributing increasingly towards food and nutritional security.

A. G. Ponniah

Food value of shrimp

J. Syama Dayal, A.G. Ponniah and K. Ambasankar
Central Institute of Brackishwater Aquaculture
75, Santhome High Road, RA Puram Chennai 600 028

Introduction

The worthiness of the food to the human being is to maintain a state of positive health and optimal performance by providing all essential nutrients in adequate quantities to prevent deficiency diseases and also chronic diet related disorders. Consuming variety of foods in balanced proportions will ensure this objective of disease free healthy life. Most of the non-communicable diseases are related to diet either directly or indirectly. The type and quantity of fat in the diet influence many of the life-style diseases along with other nutrients. The dietary intake of fats is having direct influence on the cardio-vascular disorders. The occurrence of coronary heart diseases (CHD) is influenced by diet, lifestyle and genetics. There is increasing evidence that the Indian population is more susceptible to heart diseases as reported by the results of a very recent Indian study by Sri Ramachandra University. The study which included 8080 participants indicated that vascular ageing in terms of development of vascular illnesses such as stroke, heart attack, peripheral vascular diseases, is 10 years advanced in Indian population compared to western population. Similar observation has been made earlier also by Ray (2008) in which he has shown that the susceptibility of Indian population to CHD was 3–4 times more than Americans, 6–7 times more than Chinese and 20 times more than the Japanese. These studies clearly indicate that one third of the Indian population has conditions conducive to the development of vascular diseases and it is in this context that consuming healthy food that is rich in ω-3 polyunsaturated fatty acids (PUFA) and low saturated fatty acids (SFA) has been all the more imperative.

Epidemiological studies revealed that consuming food items rich in ω-3 polyunsaturated fatty acids is associated with a reduced risk of coronary heart diseases. This was originally found in Greenland Eskimos with regular high intake of marine fishes which are rich sources of ω-3 PUFA (10-14g/day) and later also reported in several other populations including western populations with an average intake of marine ω -3 PUFA below 0.2-0.4g/ day. A meta-analysis published on fish consumption and CHD mortality based on the results from 13 cohort studies including a total of 2,22,364 individuals with an average of 11.8 years of follow-up indicated that a dose-dependent way, where each 20g/ day increase in fish intake was associated with a 7% lower risk of fatal CHD. Similar results of dose dependent reduction in coronary events in particular, non-fatal myocardial infarction (but not sudden cardiac death) with increasing intake of ω-3 PUFA were observed in an earlier study by Iso *et al.* (2006) in Japan comprising 41,578 subjects followed for 10 years. In addition to the epidemiological studies, the controlled clinical trials were also conducted to give dietary recommendations for long chain ω -3 PUFA, eicosapentanoic acid (EPA) and docosahexanoic acid (DHA). The evidence base supports a dietary recommendation of ~500 mg/d of EPA and DHA for CHD risk reduction. For treatment of existing CHD, 1g/d is recommended. These recommendations have been embraced by many health agencies worldwide. A dietary strategy for achieving the 500 mg/d recommendation is to consume two fish servings (~227g) per week (preferably fatty fish).

Shrimp is one of the world’s most popular shellfish and is part of almost every nation’s traditional meal.

The present review highlighted hereunder brings out the following facts to establish that shrimp is a high nutritious food with many health advantages. Shrimp provides high quality proteins and essential amino acids, minerals and trace elements, fat soluble vitamins and essential fatty acids including long chain n-3 fatty acids for human body. Unlike the popular perception, shrimp is a low-fat (low-calorie) source of protein. Shrimp lipid contains mostly polyunsaturated fatty acids (essential fatty acids), which includes linoleic acid and alpha-linolenic acid that are parent compounds of omega-6 and omega-3 acid series, respectively, which provide various health benefits to humans.

Food value of shrimp

The nutritional quality of shrimp is apparent from examining the protein, lipid, vitamin, mineral and carotenoid contents. Shrimp contains about 17-23% protein content and it constitutes more than 90% of dry matter. Shrimp proteins are made of α-amino acids and all the 20 naturally occurring amino acids are found in varying proportions which are highly balanced in all essential amino acids as per the needs of the human beings. 100g of shrimp is considered to provide one third to one half of one's daily protein requirement. Shrimp is also characterized by easy digestibility (85%) and has high biological value compared to proteins from many other sources. All these factors make shrimp an ideal source of protein. The shrimp contains balanced amino acid profiles as per the human requirements. The essential amino acid index (EAAI) which is a measure of quality of protein is 0.91 for shrimp indicative of its rich protein quality for humans. Shrimps are rich source of calcium, iron, zinc, iodine, phosphorus and selenium and it is a fact that the minerals are highly bioavailable (Table 1&2). Consumption of 100g of shrimp provides 100 mg of calcium and 300 mg of phosphorous meeting one third of these requirements of an adult human being. They are also rich source of vitamins, particularly, vitamins A, D, E and as well as thiamin, riboflavin and niacin (vitamin B1, B2 and B3). Shrimp contains 0.02, 0.015, 1.78, 0.16 and 0.31 and 0.16 mg of thiamin, riboflavin, niacin, B6 and B-complex vitamins, respectively in 100g. Shrimp is a rich source of fat soluble vitamins of 180 IU, 2 IU and 1.32 µg of A, D and E, respectively in 100 g. In addition shrimp also contains 2 mg% of carotenoids a fat soluble pigment known to play an important potential role in human health by acting as biological antioxidants, protecting cells and tissues from the damaging effects of free radicals and singlet oxygen. Other health benefits of carotenoids that may be related to their antioxidative potential include enhancement of immune system function and inhibition of the development of certain types of cancers.

Shrimp is one of the lowest fat content non-vegetarian food items. The average lipid content in the edible portions of shrimp is ~1%. The lipid class composition in shrimp is 65-70% phospholipids, 15-20% cholesterol and 10-20% total acyl glycerols as per our studies.

The predominance of phospholipids in shrimp lipid indicates its rich nutritional quality. Phospholipids are transport lipids present in plasma in combination with proteins as lipoproteins which play major role in transport of fat and cholesterol. Mitochondria contain large amounts of phospholipids which are essential for the organization and function of the electron transport chain which is essentially required for cellular energy production. They are also important constituents of all cell membranes and influence the membrane permeability to various substances. Phospholipids are also essential components of thromboplastin helping in blood coagulation and are present in large amounts in the nervous tissues. Grey matter of human brain contains 60-70% and white matter 40% of phospholipids, within the total lipid fraction. They are significant structural components of the phospholipid membranes of tissues throughout the body and are especially rich in the retina, brain, and spermatozoa, in which docosahexanoic acid (DHA; 22:6 n-3) constitutes <36.4% of total fatty acids.

Shrimp lipids differ greatly from mammalian lipids in that they include up to 40% of long-chain fatty acids (C14-C22) that are highly unsaturated and contain 5 or 6 double bonds. Intake of unsaturated fatty acids is better than saturated fatty acids as the latter fatty acids stimulate body to synthesize more low density lipoproteins which are 'un health cholesterol'. Fatty acids found in shrimp lipids are recognized by high degree of unsaturation (high proportions of long chain polyunsaturated fatty acids, PUFA), found in proportions of about 35-55 % in shrimp body lipids. Also, the PUFA belong to the n-3 or ω-3 groups. There is no other known food source (other than fish) that can provide n-3 PUFA in such abundance. The fatty acid content of shrimp lipids indicated 25-30% saturated fatty acids (SFA), 20-25% monounsaturated fatty acids (MUFA). Within PUFA, ω-3 fatty acids are predominant and n6/n3 PUFA ratio is 0.6-0.80 indicative of its rich health benefits to human being. Studies have clearly indicated that dietary ω-3 PUFA will augment the ω-3 PUFA level of cell membranes. ω-3 PUFAs effectively act on the properties and functioning of cell membranes – transport of materials across the cell membrane, an integral part of normal metabolic processes. Unsaturated fatty acids play an important role in maintaining the fluidity and functionality of cell membranes.

Higher ω-3 PUFA levels in cell membrane favourably alter the cardiac ion channel function and this in turn reduces myocardial vulnerability to myocardial fibrillation. The presence of high levels of the long-chained ω-3 fatty acids, EPA and DHA, are identified as one of the major benefits of ingesting fish and shellfish species derived lipids. Interestingly, small amounts of EPA and DHA can reverse an n-3 fatty acid deficiency. EPA is a substrate for eicosanoid synthesis. DHA, however, is the most abundant n-3 fatty acid present in tissues, which has led to the conclusion that DHA is the essential n-3 fatty acids. Because of the multiple, unique metabolic functions of DHA, which are not replicated by other fatty acids, it is viewed that this is the essential n-3 Fatty acid.

EPA is believed to play important roles in maintaining the health of heart and circulatory system, where as DHA are involved in the functioning of brain, nerves, etc. Various studies on the role of n-3 PUFA's influence on various metabolic processes, such as, their roles in eicosanoids metabolism, lipid protein interactions controlling membrane functions, production of cytokines, which are involved in inflammatory processes and immune systems and expression of genes associated with enzymes of lipid metabolism, which show that n-3 PUFA influence wide spectrum of basic metabolic processes and play a crucial role in maintaining healthy functioning of the system. In order to measure the propensity of shrimp eating to influence the incidence of coronary heart disease, the atherogenic and thrombogenic indices were calculated based on Ulbright and Southgate (1991) equations. Shrimp is having 0.36-0.28 of these indices which are much lower than other non-vegetarian foods indicative of its cardio-protective nature.

Table 1. Summary of fatty acid composition of shrimp

SFA (%)	30.85
MUFA (%)	20.25
PUFA (%)	38.29
P:S	1.2
ω-3 PUFA (%)	24.12
ω-6 PUFA (%)	14.17
ω-6/ω-3 PUFA	0.58
Atherogenic index	0.36
Thrombogenic index	0.30

Lifestyle-related diseases in world and in particular in India are on the rise and the causes are attributed to high cholesterol, lack of physical activity, growing stress and faulty dietary habits. In recent years, the public opinion in accordance with the latest research studies by nutritional experts is changing and they emphasize that the replacement of saturated and trans-saturated fats with unhydrogenated, monounsaturated and polyunsaturated fats are more effective in preventing CHD than reducing overall fat intake. Healthy dietary practices with regular 30 min of aerobic exercises could help to prevent CHD. Dietary management to improve the intake of ω-3 or n-3 fatty acids for normal and cardiac patients is an urgent need. Fish and fish oil consumption has positive correlation in lowering blood pressure. Delivery of n-3 PUFA fats into foods can be done in many ways, such as bio-delivery, micro-encapsulation, genetic engineering, food fortification and feeding animals with n-3 PUFA. Out of which, the best option is undoubtedly the consumption of n-3 PUFA rich foods, i.e., fish and shrimp. Fish oil is claimed to prevent a wide range of health disorders such as cardiovascular diseases, mental illness, blindness, cancer and other illnesses. Foods high in n-3 fatty acids can decrease the risk of arrhythmias that can lead to Sudden Cardiac Death, decrease the TGL levels, decrease growth rate of atherosclerotic plaque and lower blood pressure. The high levels of ω -3 PUFA intakes also help in reducing cancer, rheumatoid arthritis, mental disorders and other inflammatory conditions like Crohn's disease.

Eicosanoids are a group of compounds derived from 20 carbon PUFAs and optimum eicosanoid levels are required for regulating the functions of cardiovascular system, reproductive system, kidney function and overall functionality of the body. Changing the normal patterns of eicosanoid production can be useful in ameliorating certain forms of cardiovascular disease, osteoporosis and arthritis. These are highly active compounds present in very small concentration. Many of these eicosanoids are synthesized in the body depending upon the site of production, enzymes involved and degree of free unsaturation of precursors of fatty acids. Eicosanoids from arachidonic acid belong to 2 series, whereas those from eicosapentanoic acid (EPA) belong to the 3 series. Prostaglandins have both positive and negative effects on reproduction. Thromboxane (TxA2) promotes platelet aggregation and smooth muscle contraction. On the other hand end products of EPA eicosanoids (PGH3) act as platelet antiaggregatory and vasodilating agent.

Table 2. Summary of lipids of shrimp and other non-vegetarian food items*

Nutrient	Shrimp	*Other* NV items		Dietary guidelines	Nutritional significance of shrimp
Fat %	0.4-2 (1)	Egg Chicken Mutton Beef Pork	11 18 13 16 35	Fat should not be more than 20-30% of total calorific intake	Shrimp is the lowest fat NV item along with other crustaceans
Saturated fatty acids (SFA)	0.2-0.3 (g)	Egg Chicken Mutton Beef Pork	4 6 7 8 13	Higher SFA stimulates the *de nova* synthesis of cholesterol in the body	Lowest SFA content in the shrimp and it is good for the body
PUFA : SFA (P:S)	1.2	Egg Chicken Mutton Beef Pork	0.4 0.7 0.13 0.12 0.53	P:S should be above 0.45	Favourable ratio of shrimp lipids for cardiac protection
ω-3/ω-6 PUFA	1.5	Egg Chicken Mutton Beef Pork	0.2 0.06 0.73 0.53 0.13	Primitive man food contains ω-3/ω-6 PUFA ratio of 1. The ratio of > 0.2 is recommended	Favourable ratio of Shrimp lipids for cardiac protection, plays anti-inflammatory role, cognitive development
Cholesterol (mg/100g food)	150-200 mg%	Egg Chicken Mutton Beef Pork Brain Liver	400 100 65 70 90 2000 300	Dietary intake of cholesterol should not be more than 200 mg	Shrimp is having moderate amount of cholesterol but it is not harmful due to favourable P:S and ω-3/ω-6 PUFA ratio
Atherogenic Index	0.24-0.30	Egg Chicken Mutton Beef Pork	0.4 0.5 1.0 0.7 0.67	Lower the ratio good for the health	This index is an overall effect of dietary fat on vascular atherosclerosis Lower the value, better for health

*Data compiled from Ghafoorunissa and Kamala (2007); Enser *et al*. (1996); Chow (2008)

Unlike hormones, eicosanoids are not produced in a central location and then transported to the target organ. They act locally in the cells in which they are created and disappear quickly due to their rapid inactivation and extremely short half-lives. In general, eicosanoids bind to receptors on target cell plasma membranes in various tissues and stimulate or inhibit the synthesis of other messengers - like cyclic AMP. The proper balance of diet, in terms of availability of PUFA and the precursors for the eicosanoids are the key factors of eicosanoid-optimum functions. Among the animal protein foods, only fish and shrimp can be termed as balanced diet leading to production of eicosanoids in balanced proportions. Diets with disproportionately high arachidonic acid will lead to increase in concentrations of pro-platelet aggregatory and pro-thrombatic eicosanoids beyond desirable levels and will affect the balance of 3 series eicosanoids. This situation, combined with other factors will lead to coronary heart diseases. In the case of diet containing fish, adequate level of EPA will be available in the membrane lipids to promote synthesis of platelet antiaggregatory and vasodilating eicosanoids. The production of platelet thromboxane A3 and prostaglandin I 3 made in vessel walls in the presence of EPA by competitively inhibiting the production of pro-platelet aggregating eicosanoids.

Perceptions, concerns and facts on shrimp consumption

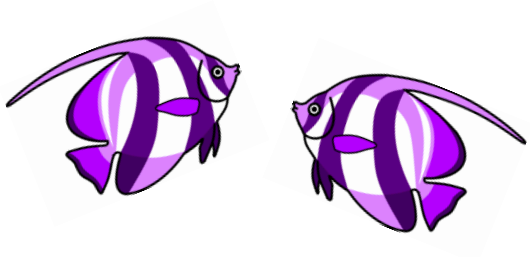
Shrimp is a rich source of protein, calcium, trace minerals, vitamins and various extractable compounds like carotenoids. Shrimp is low in total fat (1 g/100 g edible portion), and very low in saturated fatty acids and relatively high amounts of n-3 fatty acids especially eicosapentanoic acid and docosahexanoic acid, which have potential beneficial effects on atherosclerosis and thrombosis. In spite of very low fat content in shrimp, the cardiologists suggest to avoid shrimp consumption due to its moderately high cholesterol content (150-200 mg/100 g shrimp). But the cholesterol content in shrimp is much lower than hen's egg (500 mg%), liver (300-600 mg%), brain (2,000 mg%) and butter and ghee (300 mg%).

The effect of shrimp consumption on lipid profiles in humans was studied by systematic clinical trial. In a randomized study by De Oliveira e Silva et al. (1996), a diet containing 300 g shrimp/day increased low-density-lipoprotein (LDL) cholesterol by 7.1% and high-density-lipoprotein (HDL) cholesterol by 12.1 % when compared with a baseline diet matched for fat content but containing only 107 mg cholesterol/d. At the same time, the shrimp diet did not worsen the ratio of total cholesterol to HDL cholesterol or the ratio of LDL to HDL cholesterol. Moreover, shrimp consumption decreased triacylglycerol (triglyceride) concentrations by 13%. The study showed that moderate shrimp consumption in normolipidemic subjects will not adversely affect the overall lipoprotein profile and can be included in 'heart healthy' nutritional guidelines. The reason that dietary cholesterol from shrimp does not adversely affect the overall lipoprotein level could be that it is not efficiently absorbed into intestinal epithelial cells of human. This might be due to low fat content of shrimp, with bile salts and lipids, which may result in a microenvironment for shrimp cholesterol that is unfavourable for micelle formation and therefore cholesterol absorption. This supports the notion that the type of dietary fatty acid, rather than the level of dietary cholesterol, is the most potent regulator of serum cholesterol levels. Dietary cholesterol is also said to have an inverse effect in endogenous cholesterol synthesis and lower saturated fatty acids intake would have increased LDL-receptor – mediated catabolism. The reduction in triglyceride levels may be due to shrimp's n-3 fatty acid content, that are shown to decrease VLDL production, probably by increasing the intracellular degradation of hepatic apolipoprotein B. Similarly, the atherogenic index in shrimp (0.24-0.36) is much lower than other animal foods such as lamb (1.00), beef (0.72), pork (0.69), chicken (0.5) and similar to those finfish foods (mackerel, 0.28). Similar findings were reported for the thrombogenic index.

The contamination by toxic compounds may reduce the benefit of fish consumption, but eating a variety of fish should minimize this risk. The issues of allergens associated with crustaceans are of concern too. There has been concern about an increased risk of bleeding, especially after consumption of large doses of fish oil concentrates, but there is little clinical evidence in support of this even in patients treated with aspirin or anticoagulants. The risks associated with the body burden of methyl mercury and dioxins along with fish consumption on neurological/neuro-developmental outcomes in infants, immunological and reproductive dysfunctions and cancers have to be kept in mind. However the US FDA advisory (2006) and joint FAO/WHO expert consultation (2010) on the risks and benefits of fish (including shrimp) consumption, based on the strength of scientific evidences concluded that there is convincing evidence of beneficial health outcomes from fish consumption as indicated by reduction of cardiac deaths and improved cognitive developments in children. In addition, eating of fish has probable benefits in preventing ischemic stroke and possible benefits in reducing depression. The health benefits of eating shrimp is beyond n-3 fatty acids and other individual nutrients. It is the complimentary effect of the combined nutrients present in shrimp including proteins, trace minerals and beyond those other non-nutrient factors like carotenoids. These expert advisories indicate that the health benefits far outweigh the risks due to methyl mercury and dioxins. These risks are reported from fishes high in the food chain like the tunas, shark and king mackerel and are not a matter of concern in farmed fish and shrimp.

Conclusion

At present aquaculture is regarded worldwide as one of the fastest growing food-producing sub-sectors compared to cereal and livestock production since it can provide a more stable, sustainable and predictable food supply to the growing population to meet the nutritional needs. Shrimp is the richest source of protein with lesser fat content. Presence of high proportions of phospholipids and long chain fatty acids like eicosapentanoic acids and docosahexanoic acids give additional health benefits to human beings. The overall benefit of consumption of shrimp is overwhelmingly high and this is emerging as a functional food mainly due to its cardio protective character. It is for this reason US FDA Advisory (2006) clearly advocates consumption of two meals of shellfish (shrimp) per week. The adoption of this practice helps in reduced consumption of total fat and also eating of fat which is in correct proportions of fatty acid profiles for reducing diet related health problems.



Technological advances in fish harvest and post-harvest technology

T. K. Srinivasa Gopal
Director
Central Institute of Fisheries Technology
Matsyapuri, P.O., Cochin-682 029, India

India is the third largest producer of fish in the world and the second largest producer from aquaculture. The contribution of fisheries to the GDP during 2009-10 was 0.8 per cent. The fishery has emerged as a sunrise sector which provides food, employment and economic benefits to large sections of the society. It is a source of livelihood for about 15 million people engaged fully, partially or in subsidiary activities pertaining to the sector. Besides, an equal number are engaged in ancillary activities in fisheries and aquaculture. Total fish production in 2009-10 stood at 7.85 million tonnes comprising of 4.87 million tonnes from Inland and 2.98 million tonnes from marine sector. The export of fish and fish products have shown a steady growth and during 2010-11, 8,13,091 tonnes of seafood valued at Rs.12,901.47 crore (USD 2,856.92 million) were exported to nearly 100 countries. Marine fishery potential of the Indian Exclusive Economic Zone (EEZ) is estimated at about 3.93 million tonnes. About 58% of the resources is available at a depth of 0-50 m, 35% at 50-200 m and 7% from beyond 200 m depth (MoA, 2000). About 2,30,000 fishing crafts of various sizes and classes are under operation in marine fisheries, consisting of 59,000 mechanised boats, 76,000 motorised crafts and over 1,04,000 non-mechanised crafts.

While the fisheries sector is facing challenges in terms of excess capacity, resource depletion and changes in the fisheries environment in the coastal waters, under-utilised and unutilised resources such as myctophids and oceanic cephalopods in the deeper waters hold potential along with rapid expansion envisaged in the aquaculture sector and culture based capture fisheries from reservoirs. Aquaculture and culture based capture fisheries high potential for enhancement of national fish production in the coming years, when limiting factors such as deficiencies in the legal framework and policies for leasing, and difficulties in cluster based integration in harvest and post harvest operations, value addition and marketing, under value chain concept are effectively addressed.

Technological advances in harvest technology

Central Institute of Fisheries Technology has contributed to the modernisation of Indian fisheries in a very significant way. CIFT has developed and popularized standard designs of fishing vessels, suitable for various types of fishing under the Indian conditions and appropriate gear systems for trawling, seining, gillnetting, lining and trapping.

Fuel efficient fishing vessels

In view of high expenditure incurred in mechanised fishing operations, CIFT has taken initiative to develop fuel efficient fishing vessels. A 15.5 m multi-purpose deep sea fishing vessel *Sagarkripa* with steel hull was designed and developed with energy saving features. These include optimized hull design, optimized installed engine power, fuel efficient propeller and propeller nozzle. The commercial trials by the fishing boat operators have realized about 17% savings in the fuel cost.

Low-cost substitutes for conventional craft materials

Traditionally, wood is used for construction of fishing vessels in India which has become scarce and costlier. Focused attention has been given in identifying alternate materials for fishing vessel construction, in order to reduce the dependence on traditional scarce wood species. Cheaper and readily available cultivated wood species with short life cycle such as rubber wood, fortified with dual preservative treatment using 7.5% ASCU and creosote, has been identified for construction of canoes operated in backwater and coastal fisheries. A number of preservative treated rubber wood canoes have been distributed for field operations by fishermen groups and cooperatives. The cost of the canoe is 35 – 40% less than a canoe of same size built of 'anjili', the usually used wood. This saves the depleting forest wealth, helps the rubber farmer to get a better price for his under utilized wood and gives a durable, maintenance free boat at affordable cost to the poor fisherman especially of the South West and North East where rubber trees are grown. Designs of fiberglass crafts have been developed for operation in inland waters. Fibreglass sheathing as protection against borer attack and biodeterioaration and as preventive against environmental pollution while using preservative treated wood in boat construction has been popularized, in traditional sector. Use of aluminium alloy for construction of inland and coastal fishing craft has been demonstrated. Durability, light weight, corrosion resistance, toughness and resilience, low maintenance and high re-sale value make aluminium alloy a good material for construction of fishing craft.

Energy saving trawling technologies

Trawling is an active fishing method in which a bag shaped fishing gear is towed from mechanized fishing vessel. It is known to be one of the most energy intensive fishing methods. In excess of 60% of the total trawl resistance is known to be contributed by netting alone. Fuel consumption during trawling is directly related to the drag of the gear system. Substitution of large meshes in the front trawl sections has been reported to reduce the drag of the trawl system by about 7% and hence reduces fuel consumption in trawling. The reduced drag permits greater trawling speed and/or operation of larger trawl with the available installed engine power. Large mesh demersal trawls, have been extensively adopted by mechanized fishermen of north-west coast, Mangalore and Kerala, for resources like ribbonfish, squid, horse mackerel, mackerel and pomfrets, due to its low drag and fuel efficiency. Otter boards are known to contribute 20-25% of the total drag of the trawl system. Introducing camber in otter board design is known to reduce resistance of the boards considerably, by increasing the hydrodynamic efficiency of the boards. CIFT has introduced high aspect ratio, cambered otter boards for semi-pelagic trawling. Introduction of camber in otter boards reduces the drag of the trawl system by 4% with accompanying savings in fuel. This technology is expected to be adopted when the concept of semipelagic trawling become popular among trawler fishermen.

Eco friendly trawls for semi-pelagic resources

Demersal trawls are generally non-selective and a large number of non-target species and juveniles are landed during trawling, in addition to its impact on benthic communities. Resource specific trawls for semi-pelagic resources have comparatively low impact on the benthic biota. CIFT Semi-pelagic Trawl System (CIFT SPTS) has been developed as an alternative to shrimp trawling in the small-scale mechanized trawler sector, after extensive field-testing (Fig. 1). The system consists of an 18 m four panel semi-pelagic trawl with double bridles, front weights and vertically cambered high aspect ratio otter boards of 85 kg each. It facilitates harvesting of fast swimming demersal and semi-pelagic finfishes and cephalopods, which are mostly beyond the reach of conventional bottom trawls, currently used in commercial trawl fisheries in India.

Bycatch reduction and turtle excluder devices

Among the different types of fishing, trawling accounts for the highest rate of bycatch along with the target species. Almost 70-90% of the trawl catch is bycatch, among which, about 40% is constituted by juveniles that are invariably discarded resulting in two serious consequences - depletion of the resources and pollution of the marine water and the consequential threat to the ecosystem. Further, higher the quantum of bycatch the less will be the economic benefit accruing from the fishing operation. Bycatch is unavoidable in any fishing operation; only its quantities vary according to the type of the gear and its operation. Therefore, one of the important research focuses of the Fishing Technology Division was development of bycatch reduction devices. Bycatch reduction device (BRD) is a device aimed at reducing the catch of non-targeted and unwanted species of

Fig. 1. CIFT-SPTS: Eco-friendly trawl system

fish in shrimp trawling. While BRD is a broad term used to describe any device that can be employed to eliminate or reduce the bycatch, turtle excluder device (TED), though in principle a BRD, is a specialized form of BRD designed to eliminate turtles, sharks and rays also from the trawl. These devices have been designed and developed taking into consideration the differential size and behaviour pattern of shrimp and fish inside the net. BRDs include Fish Eye which is stainless steel escape chute attached in the codend for the escape of actively swimming finfishes and rigid grid devices; soft BRDs such as square mesh windows, Radial Escapement Device, Big eye, Sieve net and International Award winning design Juvenile Excluder cum Shrimp Sorting Device (JFE-SSD) are being evaluated for use in Indian waters. Sea turtles are endangered species. Various protection measures have been adopted the world over, including India, for its protection. CIFT has developed an indigenous design of the turtle excluder device which is appropriate for the Indian conditions. CIFT-TED is a single grid hard TED with top opening of 1000x800 mm grid size for use by small and medium mechanized trawlers operating in Indian waters. In the TED developed by CIFT, great care has been taken to ensure 100% escapement of the turtles while escapement of fish and shrimp at the minimum possible level.

Low energy and eco-friendly harvest technologies for the traditional sector

Improved and durable lobster traps with escape window for juveniles have been developed as substitute for traditional traps of short life span and low efficiency, for harvesting of spiny lobster. Design features: 700x550x400 mm size; mild steel rod frame mounted with 25 mm square welded mesh, plastic coated for corrosion protection.

The rich tuna resources of the Lakshadweep waters are under-exploited as the fishing operations are still limited to traditional pole and line method. CIFT has introduced large mesh gill nets and monolines (monofilament long lines) in Lakshadweep waters, for targeted fishing of tunas, billfishes, seerfishes, carangids and perches, in an effort to diversify fishing methods and improve catching efficiency. During experimental drift gill netting operations, catch rates up to 198 kg per 1000 m^2 were obtained for large mesh gill nets.

Large mesh purse seine and power block for purse seine operations

Introduction of large mesh purse seines facilitated by CIFT has led to the revival of small mechanized purse seine fishery in Kerala. The change over of mesh size in the purse seine from the conventional 20 mm to 45 mm has shown good results and the purse seiners have been able to land larger size classes of high value species. Experimental fishing operations carried out from the purse seiner *Bharat Darshan* during the period 2007-10 in the depth range of 50 to 220 m revealed that the catch mainly comprised of large sized mackerels (62.08%), followed by tunas (16.08%), Pomfrets (1.93%), carangids (14.43%) and miscellaneous fishes (5.47%). All the 75 purse seiners based at the Cochin Fisheries Harbour, Kerala have changed over to 45 mm mesh size purse seines and started operations in the deeper waters targeting Skipjack tuna, little tunnies, carangids, black pomfrets, horse mackerels, barracudas, seerfish and mackerel. The use of hydraulic power block in purse seine operations was demonstrated for the first time in small-scale mechanised purse seine sector (Fig. 2).

Fig. 2. Power block for purse seine operation

Use of advanced fish finding and navigation techniques

Recent advances in technology have provided fishermen with equipment to reach the potential fishing ground accurately (Global Positioning Systems), detect the presence of fish acoustically (echosounder and sonar), thus saving the search time and fishing time and hence saving energy. These advances in technology have been popularized among fishermen, in collaboration with agencies like MPEDA and Department of Fisheries, for bringing down fuel use and environmental impact. This, coupled with affordability and subsidy support, has resulted in significant penetration of GPS and Echosounder among small mechanized commercial fishermen, all along the coast.

Advances in post-harvest technology

The fish being a perishable commodity incur high losses at different points in the production to consumption chain. Hence it is necessary to preserve the harvested catch judiciously and minimise waste, during post-harvest operations. Present market trends reflect a rapidly growing demand for ready to cook and ready to serve convenient products. Value addition by adopting modern technologies can increase the unit value of fish products considerably. The modern technologies can assure food safety by adopting modern quality requirements through HACCP and ISO 9000 series. The recent developments have improved techniques in handling, product development, packaging, preservation and storage. Following are the brief description of development in those areas.

Chilled storage in modified atmosphere

Chilled storage in different containers has been practised in the case of fish and fish products for a long time. Modified Atmosphere Packaging (MAP) (Fig. 3) or controlled atmosphere storage by the application of CO_2 at concentrations ranging from 50 to 100% to fresh fish in chilled condition is a recent introduction which substantially increases the shelf life. The modified atmosphere retards the growth of microorganisms and reduces the rancidity in fatty fishes. Hence MAP chilled fish has an extended shelf life of 10 days or more depending on the species. Central Institute of Fisheries Technology has standardized the optimum concentration of various gases in MAP for different products to get maximum shelf life and retention of quality.

Fig. 3. Modified atmosphere packaging (MAP) system

Active packaging

Active packaging changes the condition of the package to extend the shelf life or to improve the safety while maintaining quality of the foods. The condition of food is regulated in numerous manners through the application of appropriate active packaging systems. There are two types of active packaging systems *viz.,* scavenging systems (absorbers) and releasing systems (emitters). Scavenging systems remove undesirable compounds such as oxygen, excessive water, ethylene, taints and other specific food compounds. Releasing systems actively add compounds to the packaged food such as carbon dioxide, water, antioxidants or preservatives. Most important active packaging concepts include O_2 and ethylene scavenging, CO_2 scavengers and emitters, moisture regulators, anti-microbial packaging, antioxidant release, release or adsorption of flavours and odours. Studies carried out at CIFT indicated significant improvement in the shelf life of striped Catfish *(Pangasianodon hypophthalmus)* steaks, narrow-barred Spanish mackerel *(Scomberomorus commerson)* steaks and dressed Indian Oil Sardine *(Sardinella longiceps)* in active packaging systems compared to the corresponding air packed samples.

Freezing

Freezing is the most satisfactory method for long-term preservation of fish products. The advancements in the freezing of fish products are mainly in the technological aspects of freezing and also in the introduction of newer frozen products. The freezing time in plate freezers has been reduced to more than half by the introduction of double contact plate freezers. Semi-automatic and automatic horizontal plate freezers and rotary drum types of freezers have been introduced. Spiral freezers and fluidized bed freezers replaced the conventional tunnel freezers for Individually Quick Frozen Products (IQF). These freezing systems considerably reduce the space occupied by the freezers and also freezing time. Very efficient and effective cryogenic freezing systems are also developed. Another innovation in freezing is the pressure assisted freezing. In this system freezing occurs due to the pressure induced melting point depression which enables water to remain in liquid phase at higher pressures. The melting point of ice is lowered to -22°C at a pressure of 207.5 MPa. Release of pressure enables rapid and uniform nucleation of water in a food product leading to freezing. This type of freezing produces smaller ice crystals rather than stress inducing ice front moving through the sample.

IQF products fetch better price than conventional block frozen products. However, for the production of IQF products raw-materials of very high quality need to be used, as also the processing has to be carried out under strict hygienic conditions. The products have to be packed in attractive moisture-proof containers and stored at –30°C or below without fluctuation in storage temperature. Thermoform moulded trays have become accepted containers for IQF products. Some of the IQF products in demand are prawn in different forms such as whole, peeled and de-veined, cooked, headless shell-on, butterfly fan tail and round tail-on, whole cooked lobster, lobster tails, lobster meat, cuttlefish fillets, squid tubes, squid rings, boiled clam meat and skinless and boneless fillets of white lean fish. Some of the speciality products from shrimp are stretched shrimp or nobashi, barbeque, skewered shrimp, head on centre peeled and cooked shrimp.

Drying

The water activity of fish products is reduced by drying or salting and drying. The conventional method of drying is by exposing fish with or without salting to sun by spreading over exposed surfaces which is a cause for contamination. Modifications have been made in sun drying in order to reduce contamination. Solar tent drying, drying on platforms or rack are the results of such attempts. These modified methods improve quality substantially. CIFT has developed solar fish driers (Fig. 4) having capacity with alternate back up systems ranging from 10 to 1000 kg. When solar radiation is not sufficient as during cloudy or rainy days, LPG, electricity or biomass backup will be automatically activated to supplement the heat requirement.

Fig. 4. CIFT solar dryer

Freeze drying

Freeze dried fish products are prepared by freezing the product and subliming the ice under low pressure. The structural changes in this type of drying are minimum and flavour is retained to the maximum. Some of the important types are tray freeze drier, continuous belt freeze drier, continuous circular plate freeze drier and fluidized bed freeze driers.

Radiation preservation

Use of ionized radiation for the preservation of food is a novel concept and is a truly peaceful use of atomic energy. Irradiation of fish helps in disinfestation of dried fish and extending the shelf life of fresh fish by acting on the spoilage organisms. Many of the pathogenic bacteria like *Salmonella* and *Listeria* can be destroyed at relatively lower radiation dose. Irradiation can be employed to bring about complete sterilization of the product, or for elimination of the pathogens and reduction in the viable organisms in order to improve the shelf life. The second option however, will not bring about sterility in the product. Sterilization will require higher doses of radiation and will bring about several unsavory changes in the food. At lower doses, irradiation will only pasteurize the food and hence it is necessary to hold the food at lower temperature to prevent the remaining microorganisms from multiplying and spoiling the food. Radurization of fresh fish at 1 to 3 kGy has been reported to reduce initial microbial loads by 1 to 3-log cycle and extends their chilled storage life 2-3 fold. Studies showed that irradiation of food at an overall average dose of 10 kGy produces no adverse effect and the treated foods are toxicologically safe for consumption. Radicidation of frozen fish products at a dose of 4 to 6 kGy has been found to be effective in eliminating non-spore forming pathogenic bacteria such as *Salmonella* and *Vibrio*, but is less effective in eliminating viruses and *Clostridium botulinum* type E spores. Irradiation at doses in the range of 0.1 to 1.0 kGy can prevent survival of beetles in packaged, salted and dried fishery products. Several countries have accorded clearance for irradiation of various food items following the observation of the WHO and the International Atomic Energy Agency in 1980 that any food irradiated up to an overall average dose of 10 kGy does not pose any toxicological problem.

Thermal processing

Thermal processing (canning) involves several heating processes such as cooking, blanching, pasteurization and sterilization. The objective of thermal processing is to inactivate or destroy the microorganisms and the enzymes. At the same time, maximum retention of nutrients is also very important. In preliminary cooking and also in sterilization it is observed that high temperature and short time process favour nutrient retention without sacrificing the rate of destruction of microbial spores. The major problem is the retention of some of the heat resistant enzymes by this method. The still retort is the oldest type of equipment used in sterilization or thermal processing. In conventional system the method consists of loading crates of containers into the retort, closing it and heating with steam. Improvement in the systems have centred on the mechanics of handling the containers. The recent development is the introduction of a "crate less" container handling system. Continuous retorts have distinct advantages over batch type retorts like greater production rate, lower labour cost and higher rate of heat transfer. Different types of materials are used now for making containers for canning. The main materials used are glass, tin plate, steel, aluminium and metal foils laminated with plastics. Cans made into different styles from metals like beaded cans, cemented side seam cans, two piece cans, drawn and wall ironed cans, drawn and redrawn cans and necked in cans are available. Easy open end cans and retortable pouches have been introduced and have become very popular.

Ready to serve fish products in retortable pouch

Ready to serve fish products *viz.,* curry products, in retortable pouches are a recent innovation in ready to serve fish products for local market. The most common retortable pouch consists of a 3 ply laminated material. Generally it is polyester/aluminium/cast polypropylene. Some of the products standardized by CIFT are mackerel curry, rohu curry, sardine curry, tuna curry, pomfret curry, prawn curry, seer fish moilee, pearl spot moilee, fried mussel, fish sausage, prawn kurma, prawn manchurian, fried mussel and mussel masala. These products have a shelf life of more than one year at room temperature. Retort pouches which are made up of polyester/aluminium/cast polypropylene, the product cannot be seen. During recent years pouches made up of polyester coated with aluminium oxide or silicon dioxide/nylon/cast polypropylene are available. As there is increasing demand in National and International market for ready to serve products the retort pouch technology will have a good future.

High pressure processing

High Pressure Processing (HPP) is a method of food processing where food is subjected to elevated pressures up to 87,000 pounds per square inch, with or without the addition of heat, to achieve microbial inactivation or to alter the food attributes in order to achieve consumer-desired qualities. Pressure inactivates most vegetative bacteria applied above 60,000 pounds per square inch. HPP retains food quality, maintains natural freshness, and extends microbiological shelf life. In a typical HPP process, the product is packaged in a flexible container (usually a pouch or plastic bottle) and is loaded into a high pressure chamber filled with a pressure-transmitting (hydraulic) fluid. The hydraulic fluid in the chamber is pressurized with a pump, and this pressure is transmitted through the package into the food itself. Pressure is applied for a specific time, usually 3 to 5 minutes. The processed product is then removed and stored and distributed in the conventional manner. Because the pressure is transmitted uniformly in all directions simultaneously, food retains its shape, even at extreme pressures. HPP has been used in seafood processing. HPP is used for meat separation from lobsters, oysters, clams, and other fresh products by denaturing the specific protein that holds the meat to the shell and is finding increasing applications in seafood processing.

Pulse light preservation

Pulse light technology is an emerging non thermal processing method and involves exposure of foods to short duration pulses of intense broad spectrum light. "white light", where each pulse or flash of light lasts for a fraction of a second and the intensity of each flash is approximately 20,000 times the intensity of sunlight at sea level. The spectrum of light includes wavelengths in the ultraviolet to the near infrared region. Usually a wavelength distribution having 70% of the electromagnetic energy within the range of 170-2600 nm is used. These high intensity flashes of light pulsed several times in a second can inactivate microorganisms on food surfaces. The technology can also be used to sterilize packaging materials. The material to be treated is exposed to at least one pulse light having an energy density in the range of 0.01-50 $J.cm^{-3}$ at the surface. The effectiveness of light pulse treatment depends on several factors such as intensity, treatment time, food temperature and type of microorganisms. At present, industrial applications of light pulse technology for seafood processing has been rather slow, despite its potential in this area.

Value addition

Processing adds value to the harvested resource. It has been one of the strengths of the Institute and various new products have been standardized that can be taken up by entrepreneurs at various scales of production. Emerging species in aquaculture and hitherto untapped species from wild caught production will be given more importance for product development and standardization. An important aspect of value addition is ready to eat, ready to cook and ready to fry products.

Extruded products

Extrusion is a process which combines shear, pressure and temperature leading to molecular transformations in the constituents and involves denaturation of the proteins, fragmentation of the starch molecules and changes in the non-covalent bonds between proteins, lipids and carbohydrates. Fish based extruded products have very good market potential. The advantages of extrusion

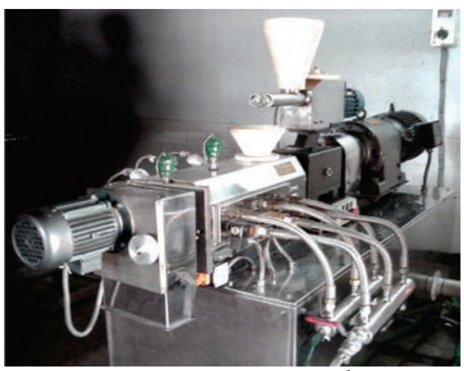


Fig. 5. Twin screw extruder

process are (i) high thermodynamic efficiency of the process, (ii) destruction of bacteria and anti-nutritional factors by high temperature short time treatment, (iii) minimisation of wastage due to one step cooking process and (iv) destruction of fat hydrolyzing enzymes during extrusion cooking. CIFT has standardized the production of extruded products by incorporating fish mince with cereal flours (Fig. 5). "Fish Kure" is one such product coated with chaat masala.

Smoked products

Smoking of fish products is a very old method of preservation. In addition to preservation, smoke imparts a particular flavour to the product. Smoking may lead to deposition of polyaromatic hydrocarbons (PAH) such as 3,4 benzopyrene which are carcinogenic. Modern smoke kilns have the facilities to control the level of PAH to acceptable levels.

Battered and breaded products

Battered and breaded products offer a convenient food valued widely by the consumer. Battering and breading enhance food product's appearance and organoleptic characteristics in addition to improving its nutritional value. Coating acts as a moisture barrier, minimizing moisture losses during frozen storage and microwave re-heating. The most important function of coating is value addition by increasing the bulk of the substrate thereby reducing the cost element of the finished product. Battered and breaded products packed in consumer packs after freezing are sold through super markets as ready to fry items. The production of battered and breaded fish products involves several stages (Fig. 6). The method varies with the type of products and pickup desired. In most cases it involves portioning or forming, pre-dusting, battering, breading, pre-frying, freezing, packaging and cold storage. Some of the important coated fish and fishery products are fish fingers, fish portions, various shrimp based products, squid products, clam and other related products, fish fillets, mince based products such as fish cutlets, burgers, fish balls, imitation products and crab claw balls.

Fish mince and surimi based products

Minced fish is the meat separated from lean whole fleshed fish in comminuted form free of bones and skin etc. Flesh can be separated from filleting waste also. Minced fish can be used as a base material for the preparation of a number of products of good demand. The properties of minced fish to a large extent are determined by the nature and quality of raw material. Meat-bone separators of different types are available for the preparation of minced fish. Minced fish from marine as well as freshwater fish is used for the preparation of a number of products like fish sausage, cakes, cutlets, burgers, balls, pastes, surimi and texturised products etc. The processes for the production of most of these products are available and some of them are very much suitable for starting small scale industries.

Surimi is the myofibrillar protein concentrate produced by repeated washing of fish mince in order to remove water soluble nitrogenous matter and flavour compounds (Fig. 7). Washing enhances the gel forming capacity of the structural proteins. Surimi is used as a raw material for the preparation of seafood analogues, but in Japan, surimi is mainly used to prepare the traditional products such as kamaboko (boiled fish paste), chikuwa (tube shaped fish paste), satsumaage (fried fish paste product) and hampen (floating type boiled fish paste). Fibreized products are the greatest in demand among the surimi based imitation shellfish products. The ingredients used in the formulation of fibreized products includes, besides surimi, salt, starch, egg white, shellfish flavour, flavour enhancers and water. All the ingredients are thoroughly mixed and ground to a paste. The paste is extruded in sheet on the conveyor belt and is heat treated using gas and steam for partial setting. A strip cutter subdivides the cooled sheet into strings and is passed through a rope corner. The rope is

Fig. 6. Coated product from lanternfish mince

Fig. 7. Surimi based analogue products

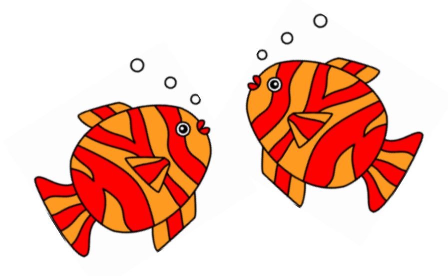
coloured and shaped. The final product is formed by steam cooking the coloured and shaped material.

Utilization of fish processing wastes and low value bycatch

It has been demonstrated that the low value bycatch and waste generated from fish processing can be used to develop novel products of high value in domestic and international markets, such as chitosan, glucosamine hydrochloride, gelatin, polyunsaturated fatty acid (PUFA), squalene, fish meal and oil (Fig. 8) . Attempts to extract new and useful compounds from waste will continue to be an area for future research.

Rapid developments have taken place in harvest and post-harvest technologies in fisheries sector, in recent years. While the fisheries sector is facing challenges in terms of excess capacity, resource depletion and changes in the fisheries environment in the coastal waters, under-utilised and unutilised resources in the deeper waters hold potential along with rapid expansion envisaged in the aquaculture sector and culture based capture fisheries from reservoirs. There is need for application of resource conservation technologies in the shelf waters under an appropriate management plan and diversification of fishing to under-utilised resources such as mesopelagics, oceanic cephalopods and large pelagics in the deeper waters. Minimisation of harvest and post-harvest losses, development of technologies for reducing carbon and ecological footprints in the harvest and post-harvest operations and value addition are areas which need focussed attention, in addition to responses to emerging issues in seafood safety and quality standards for the domestic and export markets.

Fig. 8. Encapsulated PUFA



J. K. Jena

Fish genetic resources of India and their management role and perspective of NBFGR

J. K. Jena and A. Gopalakrishnan
National Bureau of Fish Genetic Resources (NBFGR)
Canal Ring Road, Dilkusha, Lucknow-226 002, India

Introduction

Among all vertebrate taxa, fish possess the highest species diversity i.e. almost 25% of global vertebrate diversity. India with its four of the 34 biodiversity global hotspots i.e., the Western Ghats, North East Region, Himalayas and Nicobar Islands, contributes a significant share to the world's biological resources. Further, the country has been the home for about 7.4% of global fish biodiversity. Besides a source of food and nutrition, the germplasm resources also sustain other related economic activities like ornamental fish trade and various products of pharmaceutical and therapeutic value. A study by FAO projects estimates a global average per caput demand for all seafood to be about 19.1 kg in 2015. The study also highlights that the developing countries already been producing and consuming more fish than developed countries and predicts that the dominance of developing countries will grow further to 2020. To meet these challenges, appropriate planning for conservation of fish diversity and its sustainable utilization is of utmost importance.

Fisheries and aquaculture in India have been playing promising role in social development by providing nutritional security for over 650 million Indian population and contributing to the economic advancement of fish farmers, fishers and others involved in the fisheries related trade. The sector is also contributing significantly to foreign exchange earnings to the tune of US$ 2.86 billion. As the biotechnological and genomic revolutions are ready to take off, the sovereign rights of native inhabitants to intellectual property rights (IPR) related to invaluable aquatic genetic resources and associated traditional knowledge are also integral components of management strategies for genetic resources. Though Indian Fisheries Act of 1879 (modified in 1956) is a landmark with regard to fisheries, but has had no remarkable impact on the conservation of fish diversity. To conserve and optimize utilization of its bioresources, India enacted the Biological Diversity Act (BDA) 2002. This encompasses guidelines to address a wide range of issues related to the utilization of bioresources and information within the country as well as by other countries. The objective is to put appropriate procedures in place so that bioresources are optimally utilized while maintaining sovereignty over them.

Fishery resources

The inland open water resources of the country largely comprise of 29,000 km of rivers, 3.15 million ha reservoirs, 0.2 million ha floodplain wetlands, 0.72 million ha upland lakes, 0.3 million ha estuaries and 0.9 million ha backwaters and lagoons, contributing about 1.0 million tonnes of fish at present. The 14 major rivers, 44 medium rivers and innumerable small rivers of the country provide rich fish faunistic resources of 877 freshwater species. In spite of the fact that the biodiversity and conservation of the ichthyofauna in the Asian region have been relatively less documented in comparison to those of Africa, Europe and North America, available information indicate that India contributes maximum number of endemic freshwater finfish species (27.8% of the native fish fauna) followed by China, Indonesia and Myanmar. Among the four biodiversity hotspot regions in the country the Western Ghats possesses highest endemicity of about 69%. Although production break-up of the inland water-bodies of India is not available, it is evident that production from rivers and estuaries contribute only a small share of total inland catch, and that has also shown gradual decline over the years due to water obstruction structures, indiscriminate fishing and habitat degradation. However, with the increased thrust on culture-based fisheries and other forms of enhancement, the production from reservoirs and floodplain wetlands are on rise over the years.

Endowed with a coastline of 8,120 km, 2.02 million km^2 of EEZ and 0.5 million km^2 of continental shelf, India has a catchable annual marine fishery potential of 3.934 million tonnes. Although the marine fish landings of the country have shown a steady increase since last six decades, the present production of 3.2 million tonnes shows close proximity with catchable annual marine fishery potential of 3.934 million tonnes, thereby limiting scope for greater increase in production from the sector. However, the vast coast line along both east and west coast offer ideal sites for sea farming and coastal mariculture.

Species diversity of fishes in different ecosystems

According to the database of NBFGR the country possesses rich diversity of 2,358 indigenous finfishes, which includes 877 freshwater species, 113 brackishwater species and 1,368 marine species, besides 291 exotic species. Apart from the finfish resources, as many as 2,934 species of crustaceans, 5,070 molluscs, 765 echinoderms, 486 sponges and 844 seaweed species also contribute to India's rich aquatic germplasm resources. Discovery and reporting of several new species in the recent years indicate that many other underexplored areas in the biodiversity hotspots might inhabit much more number of species. The freshwater systems further possess two distinct categories of faunal resources depending on the temperature regimes *viz.,* coldwater and warmwater.

Freshwater fish diversity

Coldwater fish diversity: The aquatic resources above 914 m msl in Himalayas, sub-Himalayan zone and mountains of the Deccan are considered as coldwaters. The temperature of these upland coldwater ranges between 0 and 20°C with an optimal range of 10-12°C. With the characteristics of high transparency and dissolved oxygen, the waterbodies of high altitude possess a limited number of species diversity. Most of the fishes are small-sized, exhibiting distribution pattern depending upon the rate of flow of water, nature of substrata and food availability. Some fishes living in turbulent steams have developed special organs for attachment. The major coldwater resources are upper stretches of Indus, Ganga, Brahmaputra rivers and their tributaries as well as several coldwater lakes and reservoirs, which harbour fishes belonging mainly to six different families such as Cyprinidae, Balitoridae, Cobitiidae, Sisoridae, Psilorhynchidae and Homalopteridae. Some of the commercially important Indian coldwater species are *Tor tor, T. putitora, T. mosal, T. progeneius, T. khudree, T. mussullah, T. malabaricus, Naziritor chelynoides, Neolissochielus wynaadensis, N. hexagonolepis, Schizothoraichthys progastus, S. esocinus, Schizothorax richardsonii, S. plagiostomus, S. curvifrons, S. micropogon, S. kumaonensis, Barilius bendelisis, B. vagra, B. shacra, B. (Raiamas) bola, Bangana dero, Labeo dyocheilus, Crossocheilus periyarensis, Garra lamta, Garra gotyla gotyla, Glyptothorax pectinopterus, G. brevipinnis, G. stoliczkae* and *Lepidopygopsis typus.* The Trans-Himalayas is a fragile biome, characterized by extremes of both climatic and biotic factors. Very low productivity and a high degree of resource seasonality and unpredictability give rise to a unique diversity of life that is persistently prone to any kind of disturbance. The fish diversity of Laddakh has been very inadequately explored and according to a recent study as many as 32 fish species have been documented from Indus, Shyok and Zanskar catchment. Some of the common species are *Diptychus maculatus, Schizothoraichthys stoliczkae, Triplophysa microps, Triplophya tenuicauda, T. micros* and *Nemacheilus stoliczkae* etc.

Warmwater fish diversity: The 14 major river systems of the country sharing about 83% of the drainage possess rich diversity of commercially important species. River Ganga harbours about 250 fish species, of which about 150 are basically freshwater species. As per the available records the fish diversity of other major rivers are: Brahmaputra 167, Mahanadi 99, Cauvery 90, Narmada 95 and Tapti 57, several of which, however, are common to different river systems. Some of the commercially important species of the country include major and minor carps, *viz., Labeo rohita, Catla catla, Cirrhinus mrigala, L. calbasu, L. bata, L. fimbriatus, L. dussumieri, Cirrhinus cirrhosa, C. reba, Puntius dubius, P. carnaticus* etc.; Catfishes *viz., Clarias batrachus, Heteropneustes fossils, Sperata aor, S. seenghala, Wallago attu, Pangasius pangasius, Silonia silondia, Bagarius bagarius, Rita rita, Eutropiichthys vacha etc.;* murrels and other important species *viz., Channa striatus, C. marulius, C. punctatus, C. diplogramma, Anabas testudineus, Chitala chitala* and *Notopterus notopterus.* There are many small west-flowing rivers originating from the Western Ghats *viz.,* Chalakkudy, Periyar, Chaliyar, Sharavathi, Nethravathi etc. those are rich in fish diversity and harbour several endemic genera such as *Gonoproktopterus, Homaloptera, Bhavania, Lepidopygopsis, Horabagrus, Oreonectes, Schistura, Kryptoglanis, Horaglanis* etc. During the last decade several new fish species have been recorded from North East and the Western Ghats regions. Under NATP-funded project of NBFGR, as many as 32 new species was described from the above regions. It is assumed that many more new species could be distributed in the drainages of the Western Ghats, North East and other unexplored areas, suggesting thrust on exploration of these areas.

Brackishwater fish diversity

The major estuarine systems including Hooghly-Matlah, Mahanadi, Godavari, Krishna, Cauvery, Narmada, Tapti and other estuaries of east and west coasts, and large brackishwater lakes *viz.*, Chilka, Pulicat and Vembanad harbour majority of recorded 113 brackishwater fish taxa, the most important finfish species being *Mugil cephalus, Chanos chanos, Lates calcarifer, Etroplus suratensis, Tenualosa ilisha, Liza macrolepis, L. fade, L. parsia, Megalops cyprinoides, Elops saurus, E. machnata, Valamugil seheli, V. cunnesius, Ephinephelus tauvina, Rhinomugil corsula, Mystus gulio, Nematolosa nasus, Pseudosciaena coibor, Gerres setifer, G. oyena, Sillago sihama, Polynemus tetradactylus, P. paradiseus, Eleutheronema tetradactylum* and *Lutjanus argentimaculatus.* Among the commercially important shellfishes, the shrimps and freshwater prawn form the major groups, the major species being *Penaeus monodon, Fenneropenaeus (Penaeus) indicus, P. semisulcatus, Metapenaeus monoceros, M. dobsoni, M. affinis, M. brevicornis, Palaemon styliferus, Macrobrachium rosenbergii* and *M. malcolmsonii.*

Marine fish diversity

The marine fisheries resources comprising 1,368 taxa include commercially important finfish species like sardine *(Sardinella longiceps, S. fimbriatus, S. gibbosa, S. albella), mackerel (Rastrelliger kanagurta),* tuna *(Auxis thazard, A. rochei, Sarda orientalis, Euthynnus affinis, Thynnus tonggol)*, Bombay duck *(Harpadon nehereus)*, polynemids *(Eleutheronema tetradactylum, Polynemus indicus, P. heptadactylus)*, pomfrets *(Pampus argentius, P. chinensis, Parastromateus niger)*, seer fish *(Scomberomorus commersoni, S. guttatus, S. lineolattus, Acanthocybium solandri)*, carangids *(Caranx caranax, Megalaspis cordyla, Decapteus russelii, D. tabl)*, Silverbellies *(Secutor muconius, S. insidiator, Leiognathus dussumieri, L. bindus, L. lineolatus, L. johnesi)*, anchovies *(Coilia dussumieri, Anchoviella commersoni, A. indica, A. heterolobus, A. benganensis)*, perches *(Lethrinus spp., Epinephelus spp.)*, Catfishes *(Tachysurus thalassinus, T. tenuispinis, T. dussumieri, T. sona, T. serratus, T. jella, Plotossus canius* and *P. angullaris)*, ribbon fishes *(Trichurus lepturus, T. gangeticus, T. pantulli, Eupleurogrammus intermedius, E. muticus)*, white fish *(Lactarius lactarius)*, barracudas *(Sphyraena commersoni, S. obtusata, S. acutipinnis, S. jello)*, red mullets *(Upeneus sulphurus, U. vittatus, Parupeneus indicus)*, Malabar sole *(Cynoglossus semifasciatus)*, sharks *(Carcarhinus bleekeri, C. dussumieri, C. gangeticus, C. limbatus, Scoliodon palasorrah, S. sorrakowah)* and rays *(Narcine brunnea, Pristis cuspidatus, P. microdon)*, and shellfishes such as *Parapenaeopsis stylifera, P. hardwickii, P. sculptilis, Penaeus merguinsis, P. indicus, P. semisulcatus, Metapenaeus monoceros, M. dobsoni, M. affinis, M. brevicornis* and *Solenocera crassicornis.*

Threats to fish diversity

Habitat alterations, overexploitation of resources, construction of dams, urbanization-led diversion or reclamation of river beds, entry of exotics and above all impact of climatic change have been leading to severe threat to both biodiversity and ecosystem stability in inland water bodies. Industrial, sewage and pesticides pollution have been causing detrimental environment to fish life in many water-bodies. Hydraulic structures have changed river morphometry, flow, increased bank erosion and created barriers for migratory fishes. Dams impede upstream spawning migration of fishes and displace populations from their normal spawning grounds. Reduction of catch of hilsa *(Tenualosa ilisha)* in the upstream of River Ganga following the construction of Farrakka barrage, affecting the migration of species, has been a classical example of impact of water obstruction on fisheries. Rapid development of coastal zones has led to enormous stress on the coastal marine environment. Some of the marine finfishes threatened by indiscriminate fishing are the whale sharks *(Rhincodon typus)*, marine catfishes of the genera *Tachysurus (Arius)* and *Osteogeneosus*, the white fish *Lactarius lactarius*, the flat head *Platycephalus maculipinna*, the threadfins *Polynemus indicus* and *P. hepatadactylus*, and sciaenids *Pseudosciaena diacanthus* and *Otolithoides brunneus*. Since the gene pools and genetic diversity at large are under severe stress, sustainability of fisheries resources needs appropriate management strategies.

Over-fishing affects heritable life history parameters like growth and age of sexual maturity. Efficient gears remove large individuals, which mostly happen in the quick growing ones in the population, resulting in reduced heterozygosity since there is a positive correlation between heterozygosity with growth rate. The analysis using molecular markers in many fishes showed that heterozygosity and overall genetic diversity get reduced in a population, if quick growing lager individuals are removed by fishing. Over-exploitation of fishery resources has exacerbated the vulnerability of the population in different ecosystems, *viz. Puntius denisonii* in rivers originating from the Western Ghats and pomfrets in marine waters.

Destructive fishing in the seas and estuaries without any consideration to conserve mother and juvenile fish stock have taken a heavy toll on natural recruitment of standing stock of many commercially important fish species of low fecund groups. Fishing operations still depend on locating areas of concentrations and use of dynamite to catch more quantity from one place, bull trawling to sweep the entire fauna of the sea bottom, purse seining to catch fish shoals, and bag net fishing in estuaries to catch migrating stock of millions of juveniles during both high tide and low tide.

While exotic silver carp and common carp have shown their potential as important candidates in carp polyculture systems, their accidental entry or deliberate introduction into some of the reservoirs, have caused severe threat to the indigenous fish fauna. Significant reduction of Catla and mahseer *(Tor putitora)* in Gobindsagar reservoir in Himachal Pradesh due to accidental introduction of silver carp and subsequent establishment has shown its adverse impact. Significant reduction of snow trout, *Schizothorax* spp. and *Oreinus sinceatus* in Gobindsagar; threatened fishery of *Schizothoraichthys nigor, S. esocinus* and *S. carvifrons* in Dal lake and drastic decline of *Osteobrama belangeri* in Loktok lake of Manipur have been attributed to over-population of common carp. Introduced only during 1952 , the tilapia, *Oreochromis mossambicus* has caused severe environmental threat all across the country due to its prolific breeding habit. Overpopulation of the species found to affect the fisheries of several reservoirs and lakes in Tamil Nadu, Kerala, Karnataka and Rajasthan, and also several river systems, including the Ganga. The African catfish, *Clarias gariepinus* is another exotic that has caused serious concern due to its highly predatory and cannibalistic feeding habit. In spite of restrictions imposed by the Government of India, the species has already established its presence in most parts of the country. The species has been reported from several open waters including the River Ganga in recent years thereby posing serious threat to the natural biodiversity. Similar is the story with regard to the unauthorized entry of bighead, *Aristichthys nobilis*.

Genetic resource conservation and management

Sustainability of fisheries and aquaculture being closely linked with effective biodiversity utilization, conservation of biodiversity must receive high attention. Maintenance of balance between development and conservation of natural resources, therefore, possess great significance. Conservation of aquatic biodiversity is important from the fact that bulk of our fish production still comes from the wild. Conservation needs must be aimed towards preserving existing biodiversity and also the evolutionary processes that foster biodiversity.

Genetic resources can be viewed as genetic differences at three hierarchical levels of organization, i.e., species, populations and individuals. At the highest level, species consist of populations that are reproductively isolated from populations of other species. Genetic isolation occurs because of geographic (allopatric) or behavioural isolation and, together with local adaptation, leads to the appearance of novel genetic traits. Hence, each species harbours a unique set of genetic material. Biologists agree that the process of speciation usually occurs on timescales of several hundreds of thousands of years. However, once species are lost, several million years are required for species diversity to recover. Hence, conservation may aim at a specific species. A species becomes prominent in conservation planning for a number of reasons: i) when it is declining due to anthropogenic stress in natural waters, ii) when it is crucial for the general well-being of its ecosystem, or when it is endangered and chosen for recovery by special management measures. Sound knowledge about its biology, biogeography and genetic diversity, therefore are necessary for conservation of a declining species. At the population level of organization, the identification of discrete stocks has been a major theme in fisheries research. Biological perspective is far more important than political boundary in promoting the viability of a stock. Further, the largest store of genetic variability in most species exists as genetic differences among individuals within a population. This variability arises from the physical assortment of genes among offspring during reproduction. Conservation of this genetic variability is the theoretical concept of effective population size, which is usually much smaller than census size. It has been shown that the loss of genetic variability is greater in small populations than in large populations. Hence, the goal of preserving genetic variability in a population coincides with the goal of maintaining large ecologically sound natural populations.

Conservation involves both the *in vivo* maintenance and management of genetic diversity within the populations of a species as well as the *in vitro* storage of genetic material that can be introduced at a later time to increase or introduce diversity into the live populations. In agriculture, the problem of conserving genetic diversity has been largely framed as the preservation of domesticated plant cultivars and animal breeds, which have adapted to local environments over thousands of years of selective breeding. Technical advances have led to a greater availability of cheaper grains, and this has produced a shift from traditional methods of farming to more productive, more predictable and more capital-intensive methods of farming. As a result, farmers have abandoned many indigenous breeds, and this shift has led to the loss of genetic diversity. Much less attention has been directed towards the conservation of genetic resources in natural, free ranging capture species. The development of domesticated breeding lines for aquatic organisms is still in its infancy and depends on the availability of wild strains to a much greater degree than does the present-day development of breeds of plants and animals for agriculture.

Several arguments have been posed to support the notion that the conservation of genetic resources is important in various settings and the justifications for conserving genetic diversity are necessary to ensure the future adaptability of natural populations; to preserve life-history, behavioural and morphological traits that ensure sustainable fisheries; to promote the use of genetic resources in commerce and medicine; and to conserve genetic diversity for cultural reasons. The fish genetic resource conservation and management in the country, therefore, involve several approaches, as follows.

Documentation of fish diversity

Knowledge of species and communities can reveal crucial facts necessary for the management of ecosystems and habitats as well as to the identification of important genomes and genes. Identification, cataloguing and prioritization of species are important tasks in conservation. The database on Indian fish diversity developed by NBFGR is updated regularly to include newly described species and those exhibit new distributional ranges. In addition, it is being revised with the addition of crustaceans (prawns, shrimps and crabs) molluscs, echinoderms, marine reptiles, aquatic mammals, corals, sponges, seaweeds and seagrasses. In addition, the availability of the databases on freshwater fishes of the Western Ghats and North Eastern region, different states (Peninsular India - Kerala, Karnataka, Tamil Nadu and Maharashtra) and major rivers expected to help in conservation and management of resources of the region. Checklists of macro fauna and flora of Gulf of Mannar Biosphere Reserve (3,144 species) and the Ramsar Site-Vembanad Lake (185 species) have been prepared which will help in sustainable utilization and management of resources of the region.

In situ conservation

In situ conservation is defined as "the conservation of ecosystems and natural habitats and the maintenance and recovery of viable populations of species in their natural surroundings and, in the case of domesticated or cultivated species, in the surroundings where they have developed their distinctive properties" (Convention on Biological Diversity, Article 2). These programmes aim to develop strategies for the conservation of fish germplasm resources in their natural habitat through the integration of knowledge on fish and habitat diversity, habitat utilization, life history traits as well as human interference and other socio-economic issues. The major advantages of *in situ* conservation are: (i) continued co-evolution wherein the wild species may continue to co-evolve with other forms, providing the breeders with a dynamic source of resistance that is lost in *ex situ* conservation, and (ii) national parks and biosphere reserves may provide less expensive protection for the wild relatives than *ex situ* measures. Such conservation efforts can be meaningful only with people's participation through mass awareness programmes and involving the stake holders. In India, the protected area covers about 5.2% of the total land area, including 5,456 sites, and nine threatened fish species inhabiting these areas (IUCN).

Stock enhancement through ranching

One of the many ways in which to replenish declining natural stocks is through captive breeding or hatchery programmes. Captive breeding programmes have become the major tool used to compensate the declining fish populations and simultaneously to supplement as well as enhance yields of wild fisheries. While commercial breeding and seed production has been achieved in major carps, a few minor carps and Catfishes, greater thrust is yet necessary for development of protocol for mass-scale seed production of several other important candidate species for aquaculture diversification, several of these are threatened in their natural habitat too, which include *Chitala chitala, Ompok pabo, O. pabda, O. malabaricus, Labeo dussumieri, Semiplotus semiplotus, Clarias dussumieri, Channa diplogramme, Nandus nandus, Barbodes carnaticus, Puntius sarana,* etc. Considering the increased popularity of ornamental fish at household level and to curb indiscriminate exploitation from wild, captive seed production and rearing technology of 15 indigenous species having export potential such as *Pristolepis marginata, Horabagrus nigricollaris, Chela fasciata, Danio malabaricus, Puntius filamentosus, P. fasciatus* and *Mesonemachilus triangularis* have been standardized by the College of Fisheries, Kochi in a joint programme with NBFGR. However, captive breeding and domestication of more native species such as *Puntius denisonii, P. chalakkudiensis, Labeo nigriscens* and *Channa barca* need to be developed on a priority basis.

For a successful stocking programme, it is necessary that the genetic structure of the original wild population is determined. With the help of appropriate molecular markers like microsatellites, general information about the genetic diversity of fish populations can be established. This information can be used to develop hatchery guidelines for breeding fish for stocking purposes. By ensuring that the stocked population is having the same alleles as the wild population, reintegration of the stocked fish will likely be more successful and deviations from the original genetic structure will be minimal. NBFGR in a joint programme with the RARS, Kumarakom, Kerala successfully carried out stock-specific, breeding-assisted river ranching of two fishes *(Horabagrus brachysoma* and *Labeo dussumieri)* in Kerala; the landings of *H. brachysoma* after two years increased from 1.8% to 11 % and that of *L. dussumieri* showed an increase from 0.68% to 3.9% of the total-landings from the Vembanad Lake and adjacent rivers in the state.

Concept of State Fish

An innovative approach to fish conservation by declaring a State Fish was adopted for the first time in the country at NBFGR in 2006. This involved integration of the key stakeholders in the conservation plan where 16 states of the country became partners with NBFGR in developing strategies for conservation and enhancement of their selected State Fish in order to achieve the real time conservation success. The species identified by different states as State Fish are *Tor putitora* by Arunachal Pradesh, Himachal Pradesh, Jammu & Kashmir and Uttarakhand, *Osteobrama belangeri by Manipur, Ompok bimaculatus* by Tripura, *Semiplotus modestus* by Mizoram, *Neolossocheilus hexagonolepis* by Nagaland, *Tenualosa ilisha* by West Bengal, *Labeo calbasu* by Haryana, *Chitala chitala* by Uttar Pradesh, *Clarias batrachus* by Bihar, *Tor mahanadicus* by Orissa, *Etroplus suratensis* by Kerala, *Barbodes carnaticus* by Karnataka, and *Channa striatus* by Andhra Pradesh.

Live gene banks

A live gene bank (LGB) contributes to delisting of threatened species by captive breeding and restocking in species-specific recovery programmes. Such gene banks can contribute to recovery and utilization of genetic diversity and can be used in conservation programmes and genetic enhancement. NBFGR has established a live gene bank at Lucknow holding species of high conservation significance and with the objectives of (i) collection of threatened, endangered, and rare fish species and management of their stocks under farm conditions, (ii) study of growth, maturity, survival, and adaptability of these species in controlled conditions, and (iii) study of the life history traits of the threatened species as a tool for *in situ* and *ex situ* conservation. At regional level, NBFGR has established live gene banks in collaboration with Gauhati University and Department of Fisheries, Assam to conserve northeastern fish germplasm resources. More regional live gene banks in different agro-climatic zones are proposed in collaborative mode to accommodate more species and developing some of these repositories into 'fish parks' or eco-tourism zones to create mass awareness.

Cryopreservation of fish gametes

Storage of fish spermatozoa, eggs and embryos without loss of viability is of considerable value in aquaculture and conservation. The fish sperm Cryopreservation needs development of species-specific protocols. Such protocols are developed through experimental standardization of various parameters, after the captive breeding protocol is developed. This becomes a bottleneck due to protracted breeding season and low domestication of most of the aquatic species, especially marine fishes. Nevertheless, in all such cases, time available in a year for conducting experiment is small and determined by breeding cycle of the species. In view of the constraint, it is essential that candidate species for sperm cryopreservation are prioritized. Species-specific sperm cryopreservation protocols have been developed for 27 species including, *Catla catla, Labeo rohita, Cirrhinus mrigala, Labeo dyocheilus, Oncorhynchus mykiss, Salmo trutta fario, Cyprinus carpio, Tenualosa ilisla, Tor khudree, Tor putitora, Labeo dussumieri, L. dero, Horabagrus brachysoma, H. nigricollaris, Barbodes carnaticus, Puntius sarana subnasutus, Garra surendranathanii, Clarias batrachus, Heteropneustes fossilis, Ompok malabaricus* and *Gonoproktopterus curmuca*. Inadequate milt production or asynchronization in maturity of two sexes being an issue for induced breeding in several cultivable species, cryopreserved sperm can be effectively utilized to overcome from such milt related problems.

Fish gamete cryopreservation research still faces an important challenge in the form of long-term storage of fish eggs and embryos except the minute fertilized abalone eggs. Owing to large size, large amount of yolk and tough chorion or zona radiata with a low permeability coefficient, egg and embryo cryopreservation of teleosts and crustacea have not met with success anywhere in the world so far. Development of fish cell lines, embryonic stem (ES) cells and germ cells from Indian fishes and cloning technology as an alternative to long-term storage of finfish eggs and embryos has been emphasized. Successful protocols for grafting of embryonic cells to host embryos, for germline transmission of desired genome can be instrumental in evolving effective programmes for production of transgenics and rehabilitation of endangered species.

Tissue banking and DNA barcoding

Tissue banking is a fast mode of storing the biological material for longer durations and it can be used to retrieve genetic information and genetic manipulation studies in future. Tissue repository accessions unlike sperm banking protocol do not require species-specific protocol and at NBFGR, emphasis is given to build up tissue accessions of endemic fish species of the biodiversity hotspot regions such as the Western Ghats and North eastern region. Nearly, 12,000 tissue accessions of freshwater and marine fish species collected from mainland and island ecosystems are maintained in the tissue bank. NBFGR is also planning to establish a network of researchers across the country so that tissue accessions of all fish from different ecosystems can be made. Significant success has been achieved in developing cell cultures from *Cyprinus carpio, Chitala chitala, Labeo rohita, Puntius denisonii, P. ticto, Naziritor chelynoides, Pristolepis fasciata, Etroplus suratensis* and *Epinephelus merra.* The institute has also been serving as the national repository for fish cell lines with the financial assistance of Department of Biotechnology (DBT), Govt. of India

DNA based approach to taxon identification which exploits diversity among DNA sequences and can be used to identify fishes and resolve taxonomic ambiguity including discovery of new species. "DNA Barcoding" - DNA sequence analysis of a uniform target gene (Cytochrome Oxidase-I of mitochondrial genome) is the most recent and reliable approach to discriminate eukaryotic species including fish. Barcoding offers a simple, rapid and reliable means of identifying not only whole fish, but fish fragments, eggs and larvae. The NBFGR has recently initiated a mega programme on DNA barcoding of all Indian marine finfishes in collaboration with the global Consortium for the Barcode of Life (CBOL) - Fish BOL. DNA barcodes of more than 450 finfish species reported from Indian seas have been prepared so far as a part of the international network. This could be of great utility in sustainable exploitation, management and conservation of Indian fish species.

Genetic characterization

The primary objective of the genetic characterization is to assess the distribution and pattern of genetic variability at intra as well as inter-specific level populations, through the use of identified genetic markers. The first priority for such research is identification of appropriate genetic markers to assess the genetic diversity. The conclusions from genetic diversity data have varied application in research on management and conservation of fish species, to understand the pattern of migration of fish stocks, nature of breeding populations and also in taxonomy/ systematics. Several marker types are highly popular in aquaculture/fisheries genetics. In the past, soluble proteins, gene products (allozymes) and mtDNA markers have been popular; more recent marker types that are finding service in this field include restriction fragment length polymorphism (RFLP), randomly amplified polymorphic DNA (RAPD), amplified fragment length polymorphism (AFLP), microsatellites, single nucleotide polymorphism (SNP) and expressed sequence tag (EST) markers. The choice of markers is crucial in achieving precise information that is useful for desired application. Concerted effort has provided description of genetic variation and population structure for 15 prioritized fish species from their major range of natural distribution. These species include *Tor putitora, Catla catla, Cirrhinus mrigala, Labeo rohita, L. calbasu, L. dero, L. dyocheilus, L. dussumieri, Clarias batrachus, Chitala chitala, Tenualosa ilisha, Puntius denisonii, Horabagrus brachysoma, Gonoproktopterus curmuca, Channa marulius* and *Etroplus suratenesis.* The study covered wide geographical area and used microsatellites, allozyme & RAPD markers. Distinct population structure was observed in many of these species indicating that propagation assisted restoration programmes must be stock-specific to replenish declining populations. The taxonomic status of endangered mahseer, *Tor malabaricus* from the Western Ghats was revalidated by mitochondrial and nuclear gene sequence analysis, RAPD assay and morphometric measurements.

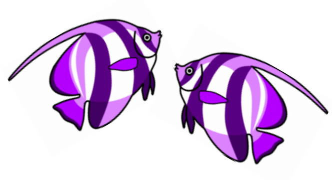
The routine population genetic studies using neutral/type II molecular markers, though useful in devising conservation strategies, reveals little about the adaptive side of the evolutionary coin. For example, the correlation between divergence of neutral markers and quantitative traits among populations of commercially important fishes can, at best, be characterized as weak. As important fitness traits in the wild are often also economically important production traits (e.g., growth, maturation, disease resistance and temperature and salinity tolerance), there will be a number of potential mutual benefits for evolutionary biology / population genomics and the aquaculture industry by gaining insights into the distribution of adaptive genomic variation in natural fish populations of the cultivable species. The link of "population genomics" with aquaculture will be capable of providing large-scale facilities for conducting controlled experiments, allowing the establishment of the 'missing' links between DNA polymorphisms, trait architecture and environmental driver of evolution. Population genomics — an emerging discipline and a new paradigm in population genetics — combines genomic concepts and technologies with the population genetics objective of understanding microevolution. Population genomics can be broadly defined as the simultaneous study of numerous functional gene loci or genome regions often using genome scans that examines genetic divergence at these loci within and among populations in time and space to identify and to separate locus-specific effects (such as selection, mutation and recombination) from genome-wide effects (such as drift or bottlenecks, gene flow and inbreeding). The degree of genetic divergence is often measured using fixation indices such as FST, with larger index values representing greater differentiation between populations. The two main principles of population genomics are that (i) neutral loci across the genome will be similarly affected by demography and the evolutionary history of populations, and (ii) the loci under selection will often behave differently and therefore reveal 'outlier' (adaptive) patterns of variation. Accordingly, there is large interest in demonstrating adaptive population divergence at the molecular level, as well as in identifying the genetic architecture of local adaptive traits conferring fitness advantages to resident individuals of species that are in aquaculture. Efforts have been initiated in NBFGR to decipher the whole genome sequence information and on population genomics of prioritized species in a consortium mode.

Exotics and quarantine

Many introductions of exotic species for fisheries and aquaculture diversification have been successful; but others have resulted in highly publicized failure, generating controversy over protection of native biodiversity, spread of pathogens and diseases. To safeguard our indigenous fish genetic resources from infectious exotic diseases and to develop effective protocols for fish quarantine, NBFGR is actively engaged in the upgradation of facilities and expertise. The NBFGR has already developed the rapid diagnostic capability for detecting the eleven fish OLE listed pathogens using molecular and immunological tools. The bureau has also succeeded in developing monoclonal antibodies against rohu, which will be extremely useful in serodiognostics for pathogen surveillance in aquaculture of Indian major carps.

Conclusion

The diverse fish germplasm of the country - a rich biological wealth, needs effective management strategies for sustainable utilization in future years and also posterity. Prospects for the conservation of fish germplasm and future strategy have to be drawn up based on past growth and the potential for future expansion, taking into consideration likely availability of funds, infrastructure and trained manpower, the impact of research data monitoring on fish germplasm and resource conservation. Maintaining the genetic health of the fisheries wealth is equally important for up-scaling aquaculture production and sustaining the fish yield from natural waters. Therefore, conservation needs must be aimed towards preserving existing biodiversity and also the evolutionary processes that foster biodiversity. The conservation of fish diversity and aquatic resources of the country requires concerted efforts by integrating capture, culture fisheries and environmental programmes using latest technological innovations. A holistic strategy is necessary to be in place to tackle the issues in inland and marine fisheries pertaining to biodiversity loss and depletion of fish stocks. It is expected that research programmes on the priority areas in consortia mode involving different research organizations, developmental agencies and other stakeholders would generate meaningful information with respect to sustainable utilization of fish genetic resources and management fisheries.



Issues related to coldwater fisheries development in India

P.C. Mahanta
Directorate of Coldwater Fisheries Research
Bhimtal-263 136, Nainital, Uttarakhand, India

Introduction

The uplands of the country are a kaleidoscope of diverse topography, climate, race, language and culture, live together and share common problems. Agriculture development has its own limits such as non-availability of the flat land and infrastructure facilities for intensive farming. Most of the population are fish eaters but the region is not self sufficient. The coldwater fisheries may play an important role in the socio-economics life of the people dwelling in the mountainous zones of the country. The majority of dependents on fish as a means of livelihood are now facing problems to meet both ends owing to sharp decline in fish catch in the upland areas. Keeping in view the squeezing land and burgeoning human ratio, mountain fish resource base is of great relevance and development of such areas becomes matter of national concern and needs different technological approach and supportive services. Such regions have to be tapped for increased fish production for national basket and rural development in hills. In Indian sub-continent, coldwater fishes are generally the denizens in the Himalayan and sub-Himalayan zones in the north and watersheds draining the southern slopes of Deccan plateau (Western Ghats). Vast water resources and diversified and queer type of fish fauna in different hill regions comprise about 258 fish species from Indian uplands of which 203 are recorded from the Himalayas while 91 form Deccan plateau.

Issues in coldwater fisheries development infrastructural issue

In the coldwater sector, most of the hill states are at different levels of development with regard to fishery development (Fig.1). The States like Jammu & Kashmir and Himachal Pradesh have during the last two decades made significant progress in capture fisheries such as sport fishery, aquaculture especially of trout, and fishermen welfare and support services.

Fig.1. Momenchu Lake of Sikkim

Inspite of these efforts the production is still very low as compared to the all India average. On the other, is the newly created State of Uttaranchal, where hill fishery did not receive adequate attention and most of the facilities are still not in place. Then there is a selective region of Northeast where the potential for coldwater fishery exists but development is at very low level. The primary reason for this situation in the country has been the lack of support at planning level and the thinking of the authorities that hill fishery is mainly a game activity and does not require R&D support. But of late it is being realized and demonstrated that coldwater fishery can contribute to food and nutritional security in hills and remote regions. Therefore, in the planning process the fishery in hills needs to be given due importance in terms of financial, infrastructure and modern institutional back-up facilities. In hills the fishery development through aquaculture, sport and conservation should be promoted and supported, in order to introduce crop-fish diversification, so that natural resource management becomes economically sustainable activity. This will result in profitable utilization of small resource base available in hills for any farming activity (Figs. 2 & 3).

Fig. 2. Typical integrated fish farm in Arunachal Pradesh

Fig. 3. Shergaon trout farm, Arunachal Pradesh

Conservation related issues

Initially, the hill streams harbored a rich population of mahseer, snow trout and minor carps, though the introduced exotic trout was only limited to a few streams. Sport fisheries, especially of mahseer and snow-trouts are well known but with the rapid overall development of the country and owing to ever-increasing demand of fish as food, the aquatic ecosystems are under constant pressure of man-induced stresses to the detriment of the aquatic flora and fauna. Though the decline of individual fish species is very often related to more than one proximate factor, the various causes of imperilment of fishes in the aquatic ecosystems have been identified by Mahanta *et.al.* (1998) and Das and Pandey (1998).

Fig. 4. Mahseer seed ranching in Bhimtal Lake

Habitat destruction

Siltation from the catchment areas, besides changing the ecology due to construction of dams, has destructed the feeding and breeding grounds of many fishes. It is estimated that about 5,334 million tons of soil are eroded Annually from the cultivable land and forests of India. Our rivers carry nearly 2,050 million tons of silt, depositing approximately 480 million tons to the reservoirs causing eutrophication and reduction in the productivity of the water bodies. Habitat alterations in Himalayan waters have affected distribution and abundance of native fishes in mountain streams of India (Fig. 4). Power dams and reservoirs have dramatically changed the fish habitats and local fish communities. The migration routes of important native fishes like mahseer (*Tor putitora* and *T. tor*) and snow-trouts *(Schizothorax richardsonii, S. plagiostomus)* have been blocked (Fig. 5). Excessive withdrawal of water from the river courses for agriculture, domestic and industrial uses leaving inadequate water for comfortable fish life is also a major factor responsible for the depletion of fisheries resources.

Fig. 5. River course diversion

Wanton destruction

Wanton killing by the use of dynamites, electric shocks (Fig. 6) and poisoning of brood fishes in spawning season and juveniles during post monsoon periods have affected a number of food and game fishes of upland waters, especially in rivers and streams originating in Assam, Nepal, Bhutan, Garhwal, Kumaun and Himachal Pradesh. Mass killing of fishes of all the sizes

Fig. 6. Indiscriminate fish killing in Garhwal

during summer months in pools formed in river courses is an alarming situation, particularly in Ganga which does not retain many waters during summer now-a-days. Anthropogenic pressure such as increased water abstractions, wanton methods of fishing and pollution in the upland fisheries resources altered the systems. The coldwater fishes such as *Tor tor, Tor khudree, T. putitora, Schizothorax richardsonii* and *Schizothoraichthys progastus* have been included in the threatened/vulnerable list.

Aquatic pollution

Pollution is probably the single most significant factor causing major decline in the population of many fish species. Chemical pollution from factories and plants situated in the Nilgiris, Mysore and Croog have exterminated certain groups of hill-stream fishes available in local aquatic habitats. Certain Noemacheiline loaches recorded by Day from Bhawani river at Mettupalayam, Coimbatore district are no longer available.

Introduction of exotic species

Brown trout *(Salmo trutta fario)* and rainbow trout *(Onchorhynchus mykiss)* are the two species, which constitute trout fishery in the streams, lakes and reservoirs in the Indian uplands. In the Himalayan region, *Salmo trutta fario* is the only trout which supports sport fishing, while in the Southern region rainbow is the principal one. Common carp mainly includes two phenotype *viz.,* scale carp, *Cyprinus carpio (communis)* and mirror carp, *Cyprinus carpio (specularis)* which constitute the bulk of the commercial fishery of certain lakes and reservoirs of J&K, Himachal Pradesh, Uttaranchal, North-Bengal, Arunachal Pradesh, Nagaland, Meghalya, Tamil Nadu and Kerala. A third phenotype, leather carp, *Cyprinus carpio (nudus)* is of very rare occurrence. A good amount of data has been generated reflecting that introduction of *Cyprinus* has been responsible for decline in local snow-trout fishery in some of the upland lakes. Now the commercial catches of *Cyprinus* have nearly increased to 70-80% in most of the upland lakes reducing the contribution of local variety to nearly 10%. Except in the lakes of Kashmir, the lakes/reservoirs in many other upland states have been stocked with silver and grass carp in order to increase the per hectare yield from the system. This practice in some has increased the per unit productivity but has resulted in sharp decline in indigenous fishery. Majority of fish production from the upland regions is fundamentally based on the contribution made by these exotic carps. On this issue one would argue about the conflict between increased fish productivity and preservation/ conservation of indigenous biodiversity, both issues are equally important.

Management issues

Coldwater Fisheries management was more of resource management till recently. Moreover, it was more or less uni-sectoral in approach. Even today, pollution abatement, geomorphological changes, resource harvest and developmental activities are not addressed in an integrated single table. But with the changing times and in the face of availability of modern information, management has been becoming highly integrated. The subtle or not so subtle lapses between integrated methods and non integrated methods are many. In view of these, plans of integrated approach have emerged and are being practiced.

Capacity building is a cherished activity in this century and has been made easier by both the technology and the availability of funds (Fig. 7). Although it is impossible to precisely estimate the needed quantified capacity by the society, qualitative approaches of defining the components of capacity are in vogue. So there are ideals on what should be the capacity. These ideals depend on country context social expectations, global parameters and a context specific vision of the future. But more often than not, there is a gap between ideal and reality and the gap could subtly enlarge and seal the fate of development. Realities emerge from rapid changing technology, systematic inertia, transfer loss in knowledge, speed of capacity building, lack of appreciation of vision and/or irrelevant follow up of programmes. Examples in the world are not too few in this matter. One of the foremost risks in capacity building is that there are subtle areas of capacity leaks which do not attract as much attention.

Fig. 7. Vocational training

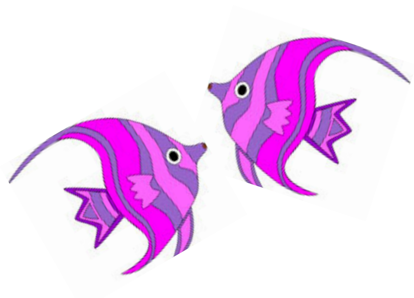
Policy issues

The aquatic resources in hills are quite valuable for the development of fishery both for food and sport, but scientific management of these resources is necessary to achieve the objectives. In order to manage these ecosystems, so that they can contribute to fishery development in remote hilly regions on a sustainable basis, the following issues need attention.

a) Practically all the water resources suitable for hill fishery in the state are owned by the forest/irrigation department. For implementation of fishery development programme there is a need to place them under the management of fishery department
b) Construction/renovation of existing fish farms and hatcheries on a priority to promote aquaculture activities
c) A balanced strategy for lakes, for tourism and fishery development is required
d) Hill fisheries conservation: In steams *vis-à-vis* other users of the resource
e) Development of sport fishery: In linkage with tourism department involving creation of angling facilities and ranching of mahseer and trout in streams
f) In natural ecosystems need enforcement of protective legislation and adopting aquaculture practices on a large scale
g) Breeding grounds should be declared as sanctuaries at least during the breeding season

Conclusion

Uplands have been a source of resource and service to the mankind for long. They have been used for procuring food, energy and minerals. While we look at the uplands as a supporter of our lifeline we also have to be conscious of the abuse and misuse. While uplands provide light for life we should not cast an abusive shadow. Sometimes the shadows are so subtle that we fail to recognize them or we ignore them. For example, mining, tourism etc. are activities, which may not have immediate effects but may be cumulatively harmful on a long run. Fragile upland environment draw the human attention in different ways. Human intervention is not only in view of resource exploitation but also towards protection of the environment for future. However, it is a matter to consider that good intentions too could prove our lifeline; we also have to be conscious of the abuse and misuse ineffective if not supported and sustained by appropriate information and knowledge. The wise practice philosophy has a comprehensive vision of looking for details of risks and risk mitigation concepts. It is only after recognition of details that a possibility of generating global prescriptions for wise management practices would emerge. It requires effort and time to analyze various activities in the uplands that are coordinated under diverse technological, social and cultural backgrounds. It is surely laborious and time consuming to unravel the hidden unwise components of plans and programmes and initiate ways of countering their effects. But it is a necessity and an investment for a safe and wise future.



S. K. Ambast

Status, issues and strategies for development of fisheries in Andaman and Nicobar Island

S. K. Ambast and Kamal Sarma

Central Agricultural Research Institute Port Blair – 744 101

The Andaman and Nicobar group of Islands consists of 572 islands having an aggregate coastline of 1.912 km, which is about a fourth of the coastline of India. These Islands encompass 0.60 million sq. km of the Exclusive Economic Zone (EEZ), which is about 30% of Indian subcontinent. This provides a great opportunity to exploit the vast resources of the seas around these Islands to our advantage. At present 1.48 lakh tones of fishery resources are estimated to be available for exploitation from Andaman, but present level of exploitation is only 20% of the potential. Thus, there is vast opportunity for developing fisheries as one of the leading sectors for A&N islands. The paper discussed here will try to unravel the strength, weaknesses, opportunities and threats in fresh water, brackish water and marine sectors with issues on infrastructure, harvest and post-harvest as well as the upcoming trends in bio-prospecting from Andaman Sea.

A. Freshwater sector

Islands face a severe crunch of terrestrial land resources and freshwater. With the intrusion of seawater to inland post-tsunami, the formation of brackish water is detrimental to normal crop and livelihood activity and farmers have to face continuously the complex problem of water availability and salinity. Thus, one of the main limiting problems in the island is the availability of freshwater for drinking, agriculture and industry. Since forestland occupy nearly 86% of available land area, the pressure on revenue land is high and water as a resource is becoming highly priced day by day. Freshwater resources for domestic consumption and other regular uses is the top priority in the urban areas, but can be a viable option for irrigation and other utilities in rural and remote islands.

Freshwater aquaculture plays a very important role in livelihoods of local communities. Indian Major Carps, Catfishes and freshwater prawn mainly contribute to the total fresh water fish production. On an average island produce about 100 -120 t of freshwater fishes annually. At present ANI consists of 1870 minor irrigation ponds with total water spread area of 114.35 ha used for pisciculture purpose and 367 ha of reservoir area (7 numbers). The main fish culture areas are concentrated in Port Blair, South Andaman (488 ponds, 26.13 ha) and in Digilipur, North Andaman (473 ponds, 28.97 ha).

Though freshwater aquaculture practice is adopted by farmers of Andaman, the availability of quality seeds (spawn, fry and fingerlings) are the main problem hindering the pace of development in the Islands. At present there is no well organized commercial seed production unit in Andaman. Every year Department of Fisheries, A&N and Central Agricultural Research Institute, Port Blair are producing fish seed and distribute the seeds to the farmers, but total demand is much higher than the supply. Due to excess demand, fish seeds are being illegally imported from mainland. Apart from being costly, illegal import of fishes creates a vulnerable condition to the endemic as well as existing stock of fishes, increases disease outbreak and introduces some unwanted aquatic species. Hence, considering the demand and concern, it is imperative to establish few seed producing units at Andaman which can supply seeds consistently to the needy farmers. Apart from supplying quality fish seed, CARI has successfully developed and demonstrated several technologies like small scale seed production unit, composite fish culture, magur breeding and culture, integrated farming practice etc. Pond based IFS programmes for such fresh water bodies, where the fish occupy the living space and the surplus water of the pond is available for irrigation and the banks of those ponds for agri-horticultural crops is an important model highly beneficial to the farming community. The Broad Bed Furrow (BBF) is another useful technique for island condition developed by CARI. In the BBF, the raised broad bed areas are used for cultivating seasonal vegetable or fodder crops during monsoon season months and depressed area used for rice and fish cultivation. In experimental studies carried out at CARI, significant quantities of fish production could be achieved which contributed to the total income of the farmers.

B. Brackishwater sector

ANI have around 1,10,000 ha brackishwater/salt affected area besides 966 sq. km of mangroves. After tsunami, another 4000 ha has become brackish due to salt water intrusion and out of this 1000 ha have been identified potentially suitable for aquaculture. The total area now available for development is 1680 ha where the saline/brackishwater will be available for taking up aquaculture in ponds/cages/pens, etc. Brackishwater aquaculture is insignificant in the islands and only < 10 ha are currently under culture. However there is tremendous scope for development of brackishwater areas. After tsunami large area became inundated by seawater and can be categorized into three situations:

1. Situation I: Low lying coastal areas where there is permanent stagnation of seawater and the depth of impounding increases with high tide.
2. Situation II: Low lying coastal areas where seawater reaches with every high tide and recedes with low tide.
3. Situation III: Low lying coastal areas where seawater intruded only during Tsunami and then receded permanently.

For brackishwater culture purpose, a pond has to have a minimum of one meter water depth throughout the culture period. Hence, areas coming under situation I, can be used for fish culture purpose, however, for situation II slight modification is necessary as water level will continuously fluctuate. For situation II, to maintain water depth to a minimum of 1 m, bundh or dyke has to be erected along with self operated sluice gate system for entry and exit of water. Second situation will be better for those species require regular water exchange like shrimp. If sluice gate is made with proper design, apart from water exchange, complete draining of the water will also be possible. This will reduce harvesting cost significantly. There are many species that can be cultured profitably in the brackishwater. However, due to scarcity of seed and other input materials, only few are becoming popular in India. Few important species like seabass, shrimp, mudcrab and mullets are some of the important candidate species that can be cultured in Andaman.

Tiger shrimp are cultured extensively in the brackishwater areas of India yielding lot of export earnings. However, recently due to WSSV, shrimp culture has been severely affected in the coastal states of India. Very high stocking density and poor water quality management are some of the causes of this disease in mainland. Due to high tourist inflow, rate and demand of tiger shrimp is also very high in Andaman (> Rs 500 per kg). Though the presence of WSSV has been detected in shrimps of Andaman no clinical symptom has been reported so far. With low stocking density extensive shrimp farming practice with an average production of 1- 1.5 t /ha can be obtained in Andaman. Apart from shrimp farming, culture of a few other important brackishwater fishes can also be carried out in Andaman. On experimental basis CARI has conducted culture practice of a few important brackish water species and developed several models for promotion in the inundated areas. One of the potential candidate species identified for tidefed brackishwater areas is Mudcrab. Production of 600 to 950 kg/ha can be achieved in Andaman. Also milkfish culture (estimated production of 600 kg/ha/year); mullet, *Liza tade* culture (estimated average production of 232 kg/ha) and seabass culture (estimated production in 10 months culture period was 3 tonnes with 66% survival) can be done in the brackishwater areas in Andaman.

Another integral component in brackishwater ecosystem of Andaman is the mangrove. They can withstand severe environmental stresses including alternate mixes of freshwater and saltwater, prolonged submersion or exposure with every tide and mud with no oxygen and high sulphur content. They act as a barrier zone between saline water and terrestrial land mass and are also important to humans for a variety of reasons, including aquaculture, agriculture, forestry, protection against shoreline erosion, as a source of fire-wood and building material, and other local subsistence use. Mangrove zones are highly productive and renders a habitat for at least a part of the life cycle of a number of coastal biota. According to FAO 2004 about 30% of all commercial fish species are mangrove-dependent producing an annual catch of almost 30 million tonnes globally in 2002.

ANI are endowed with about one fifth of the country's extensive and diverse mangroves. Mangroves constitute about 10.85% of the total forest area of these Islands. As far as density and growth are concerned, the mangroves in Andaman and Nicobar Islands are probably the best in our country. There are 34 true mangrove species belonging to 15 genera, 10 orders and 12 families from Andaman. Apart from that there are mangrove associates comprising of herbs, ferns, creepers, vines, shrubs, trees and orchids which are mostly found in the landward margins. However, off late the mangrove on Andaman is also facing severe stress due to human interference, anthropogenic factors as well as due to climate change related issues. Human interface on mangroves cannot be avoided in a coastal agro-ecosystem as the available pressure on land area make people look into mangroves for alternate livelihood. CARI took an initiative in collaboration with the Forest Department to look into the mangrove ecosystem as a livelihood source for the residents of the coastal fisherman against their conventional perception of cutting the mangroves for wood and converting the lands to a cultivable one. A demonstration farm for mangrove-based agro-aqua farming has been developed adjacent to the creek in Sippighat within the Brackishwater Farm complex of CARI. It demonstrates sustainable aquaculture where stocking and harvesting will be done round the year without supplementary feed and the same is advocated for the areas adjacent to the mangroves in Andaman. The income from the fish harvest will be supplemented through judicious integration of other agricultural components. Total economic value of mangrove for the ANI was worked out using product and market value approach and it was estimated to be over Rs. 12,000 crores, which translates to about 2 lakh worth tangible and intangible benefits to every stakeholder of the islands on an average.

C. Marine sector

Marine sector can be categorized into three broad areas: mariculture, resource for sustainable harvest and characterization of coastal bioresources.

Mariculture

With a vast area of proceed bays, continental shelf area and sandy beaches, the islands have a huge potential for mariculture related activities. Cage culture, marine ornamental fish seed production, live feed for aquaculture utilizing the recorded brachionid resources of the islands and algal resources from culture as a bio-refinery to resolve the energy requirement of the islands are certain areas where the institute has put efforts to develop a technology.

Capture fisheries

The marine fishery resource potential in EEZ of this islands is estimated as 1,48,000 mt, which comprises of demersal resources (32,000 mt), neritic-pelagic resources (56,000 mt) and oceanic resources (60,000 mt). The aggregate potential yield of fishery resources in the EEZ around Andaman and Nicobar Islands forms about 10% of the total projected fishery potential of the entire Indian EEZ. However, present level of exploitation is far below its potential. On an average about 30,000 tonnes of fishes are being harvested annually from Andaman waters. The coastal tuna and oceanic tuna fishery resources aggregate to an estimated fishery potential of 64,500 mt (18,000 mt of coastal tuna and 46,500 mt of oceanic tuna). The average catch of tuna is 1,122 mt, contributing only 1.74 % to the fishery which is mainly of coastal tunas. It is high time to implement strategies for targeting the tuna resources, which account for about 75% of the fisheries potential of the islands. Other important marine fishery resources of these Islands are mackerels, sardines, carangids, silver bellies, perches, anchovies, hilsa, mullets, elasmobranchs, seer fishes, shrimps and crabs and mostly under utilized. There are 97 fishermen villages in ANI with a population of 15,320. Around 7,204 active fisherman are engaged in marine fishing activities in the Islands. There are about 3,114 number fishing crafts comprising of 1,620 traditional crafts, 1,431 motorized crafts and 63 mechanized boats. Gillnet is the main fishing gear used in Andaman, which contributes to nearly 40% of marine fish landings followed by hook and line about 21% (average 1993-2002). The other fishing gears commonly used are cast net, shore seine, anchor net, disco net etc. There are 57 beach landing centres and 8 fish markets. Efforts are to be made to introduce medium-sized and larger vessels, which can fish in the distant and deeper waters by using eco-friendly fishing methods namely tuna long line.

Due to remoteness of the islands, available craft and gear and time required for scouting the potential areas for fishing, the fish stock is still under - utilized. In this regard, CARI in collaboration with Indian National Centre for Ocean Information Services, Hyderabad, has demonstrated that Integrated Potential Fishing Zone (IPFZ) forecasts can be potent tools for harnessing the under-exploited fishery resources of the Island. From the validation studies, it was proved that by following PFZ advisories there is an average increase in total catch by 30.37%, 30.03% and 23.80% for gillnetters, trawlers and longliners respectively. Apart from increasing production, PFZ advisories also reduce the scouting time and thus decrease the usage of fuel and operational costs. The benefit cost ratio following PFZ advisories was found to be the highest (3.47) in case of trawlers followed by that of long liners (3.26) and gill netters (2.60).

Apart from this, CARI also has taken significant initiations for assessment of important marine stock of Andaman especially on grouper and snapper fishes which are exported from Andaman.

Coastal bioresources

Apart from the exploitable marine resources, Andaman Sea harbour numerous organisms many of which are yet to be documented and studied. Sponges and sponge associated bacteria are one of the important groups least studied but have a high potential for bioprospecting. Central Agricultural Research Institute, Port Blair has made significant contribution for identification and cataloguing of those organisms. Globally over 8,000 sponges have been described while from India only about 486 sponge species have been reported including 75 from the Andaman (about 15%), which perhaps could be more, in the light of the rich marine biodiversity of the Islands. Altogether 51 marine sponges were collected of which 27 have been described through conventional taxonomy. Antimicrobial assay of host *vis-à-vis* the associated bacteria was carried out for few sponges. As per the preliminary observation it was found that the many sponge associated bacteria displayed higher inhibitory bioactivity than their hosts and can be potential source for bioprospecting.

D. Climate change and associated problems

ANI is one of the most vulnerable regions in our country due to climate associated eventualities, geographical isolation, flat topography and limited physical size rendering coastal retreat impossible. These islands lie in the most severe seismic zone and hence the adaptation strategies need to be evolved not only for the gradual sea level rise but also for storm surges, tsunamis and flooding due to land sub-duction. CARI has made significant contribution in preparing the vulnerability map for Nicobar Island. Based on the estimate the loss of land would be maximum in Chowra (13.34 %) where over 13% of island will be inundated with a 0-10 m high surge in the Nicobar group of island. Another important climate associated problem is the rise in Sea Surface Temperature (SST) in the Andaman waters and its effect on coral reef.

ANI are blessed with the richest coral diversity of India. Tourism is supported by the beautiful and biologically rich coral reef ecosystem. A total of 177 species of hard corals falling under 57 genera have been reported from these islands. However, in recent times these coral reefs are experiencing unprecedented levels of degradation due to human interference and climate change. For more than two decades CARI has been involved in monitoring and assessment of the reef health and their responses to climate change. Periodic surveys conducted to assess the reef health across different islands in Andaman indicated that the reefs suffered extensive bleaching (up to 70%) during May 2010 due to elevation of sea surface temperature. The bleached reef associates have fully recovered, massive corals are recovering while all the affected branching corals (*Acropora* sp.) have died. Unless proper conservation/ management measure is initiated, coral reefs and many of their associated animals may cease to exist within the next few decades. Anthropogenic disturbances also results in proliferation of obnoxious polychaetes which disturb the corals in South Andaman.

E. Fish processing and value addition

At present only a small quantity of fishes and crabs are being exported from Andaman (700-800 t per year) . However, with the development of fishing technology, the importance in this sector has improved significantly. A&N administration is also taking various steps for development of fish processing and value addition units. For efficient utilization of tuna resource, administration declared a novel programme " Tuna Mission" and several schemes have been floated under this programme like subsidy for purchasing bigger size boats that can be used for tuna fishery, cold storage, freezing plant, strengthening of the harbor infrastructure etc. However, in spite of several schemes, response from the entrepreneur and fishermen is limited.

F. General issues for development of Island Fisheries

a) Administrative

- Inaccessibility of many coastal areas especially on the western sides of the island.
- Foreign poaching
- Pollution from land drainage
- Introduction of diseases due to import of fishes from mainland
- CRZ notification and CAA regulation for the development of brackishwater farming in the island

b) Developmental

- Lack of indigenous expertise/technologies and lack of trained personnel
- Lack of local capacity for capital investment on high cost ventures
- Poor infrastructure for large scale fishing and coastal/offshore aquaculture
- Inadequate processing and marketing infrastructure
- Salination of ground water resources and degradation of agricultural fields
- Impacts due to improper government policies for fisheries promtion like total banning of exploitation of certain species

c) Research

- Lack of reliable database on the magnitude and dynamics of exploitable and cultivable aquatic resources
- Lack of data on possible over-exploitation of specific resources through target fishing
- Lack of data on the impact of climate change on different coastal bioresources and the fish stock
- Captive broodstock and seed production of species suitable for mariculture
- Technology for marine ornamental fishes
- Technology for identifying fishing grounds round the year, in the light of prolonged rainy season prevalent in islands.
- Exploitation of coastal and deepsea bioresources for their bioactive potential

G. CARI's Interventions

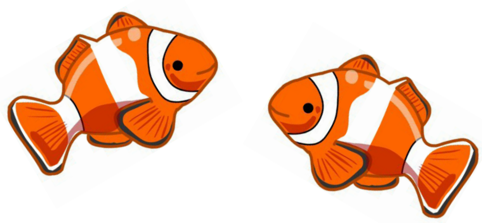
a) Research and technology transfer

- Standardized the technology for seed production and farming of various freshwater candidate species like Indian major carps, freshwater prawn and catfishes
- Developed a model brackishwater farm and the technology for the culture of mudcrab fattening, milkfish, seabass and mullet
- Validated the Potential Fishing Zone in the islands and conducted periodic awareness campaigns across the islands (300 campaigns during 2007-2011)
- Documented the biodiversity of coral reefs and mangroves and the associated fisheries resources
- Extensively studied the impact of elevated sea surface temperature on coral reefs in Andaman and determined the extent of bleaching
- Conducted feasibility studies on the cage culture in protected bays and creeks; mariculture of green mussels and edible oysters

b) Influencing Policy

- Contributed in the drafting of the roadmap for fisheries development in the islands – ANDFISH, commissioned by the A&N Administration during 2005
- Conducted a brainstorming on Development of Island Fisheries during 2008 involving all the stakeholders *viz.*, representatives of fishermen and farmers, local administrators, fisheries scientists from local and mainland institutions, policy makers, etc

Pressure is building upon the Indian marine fishery resources, which are facing over - exploitation threats. But Island fisheries are still looking up for optimum and sustained exploitation of its fishery resources. For satiating the internal demand the freshwater sector has to be strengthened. There are potential avenues for fisheries growth in marine, brackish and freshwater sectors which can augment the post-harvest sector. It is imperative to divert financial and administrative attention to island fisheries sector for a sustainable development of the Islands.



Local Organising Committee

Reception

Dr. E.V. Radhakrishnan (Chairman)
Dr. Mary K. Manisseri
Dr. G. Gopakumar
Dr. V. Kripa
Dr. K.K. Vijayan
Dr. K. Sunilkumar Mohammed
Dr. P.U. Zacharia
Dr. Grace Mathew
Dr. V. D. Deshmukh
Dr. Rani Mary George
Dr. G. Maheswarudu
Dr. R. Narayanakumar
Dr. T.V. Sathianandan
Dr. K.K. Philipose
Dr. A.P. Dineshbabu
Dr. M.S. Madan
Dr. P. Kaladharan
Dr. Mohammed Koya
Shri Rakesh Kumar
Dr. A.R.T. Arasu
Dr. S.M. Pillai
Dr. N. Kalaimani
Dr. M. Natarajan

Registration

Dr. V. Kripa (Chairperson)
Dr. R. Narayanakumar
Dr. Imelda Joseph
Dr. K.S. Shobana
Dr. Laxmilatha
Dr. Boby Ignatius
Smt Rekha J. Nair
Dr. D. Prema
Dr. Somy Kuriakose
Dr. Shoji Joseph
Dr. Jayasree Loka
Dr. K.G. Mini
Dr. Sobha Joe Kizhakudan
Shri. K.R. Sreenath
Shri. Gyanaranjan Dash
Dr. Biswajit Dash
Mr. Suresh Kumar M.
Smt S. Gomathy
Smt I. Santhosi
Dr. M. Poornima
Dr. P. Nila Rekha

Abstract (Invitation, Programme booklet)

Dr. A. Gopalakrishnan (Chairman)
Dr. K. S. Shobana
Sr. Rani Palanichamy
Dr. Somy Kuriakose
Ms.Rekha J. Nair
Dr. Srinivasa Raghavan V.
Dr. Rekha Devi Chakraborty
Dr. Raja Swaminathan T.S.
Dr. Najmudeen T.M.
Dr. K.G. Mini
Dr. K.P. Jithendran
Dr. G. Gopikrishna

Souvenir (Contact – articles & ads, Receipt, Editing, Print)

Dr. C. Ramachandran (Chairman)
Smt. T.S. Naomi
Dr. D. Prema
Dr. Joe Kizhakudan
Shri. V.S Basheer
Dr. Shyam Salim
Shri. Edwin Joseph
Shri J. Narayanaswamy
Dr. C. Gopal
Dr. M. Kailasam
Dr. T. Ravishankar

Local Secretariat at Venue

Dr. R. Jeyabaskaran (Chairman)
Dr. Srinivasa Raghavan V.
Shri Devassy
Shri Ramamurthy
Shri K.S.S.M. Yousuf
Dr. S. Sivagnanam
Mr. R. Subburaju

Media coverage (pre-conference meeting, daily press release etc.)

Dr. R. Narayana Kumar (Chairman)
Dr. C. Ramachandran
Dr. (Mrs.) R. Geetha
Shri P. Thirumilu
Dr. V.S. Chandrasekharan
Dr. M. Kumaran

Session Management (coordination with Chairpersons, rapporteurs : audio & video supervision, presentation)

Dr. G. Gopakumar (Chairman)
Dr. K. Vinod
Dr. Pratibha Rohit
Dr. P.S. Asha
Dr. J. Jayasankar
Dr. Boby Ignatius
Dr. Sujitha Thomas
Dr. Geetha Sasikumar
Ms. Muktha Menon
Ms. Anulakshmi Chellapan
Dr. Divu Damodaran
Shri Joe Kingsley
Shri Puhalendi
Shri Padmanabha
Shri Manu
Dr. S. Alavandi
Dr. M. Muralidhar
Dr. M. Jayanthi
Dr. J. Shyamadhayal
Dr. M. Sashi Sekhar

Finance

Shri A.V. Joseph (Chairman)
Shri R. Anil Kumar
Shri P. Krishnakumaran
Smt K.N. Meera
Smt Anis Mary Paulose
Shri Rishikesh Aandi

Kit, Momento, badges + Food coupons + certificates

Dr. E. Vivekanandan (Chairman)
Dr. M. Rajagopalan
Dr. R. Geetha
Shri K.S.S.M. Yousuf
Dr. S.K. Otta
Dr. R. Saraswathi

Liaison with Event Manager

Transportation (pick-up, drop, daily transport to venue & back)

Dr. G. Mohanraj (Chairman)
Dr. I. Jagadis
Dr. Abdul Nazar
Dr. M. Sakthivel
Dr. Johnson B.
Shri S. Mohan
Shri P. Poovannan
Dr. A. Panigrahi

Accommodation

Dr. Joe Kizhakudan (Chairman)
Dr. K.K. Phillipose
Dr. P. Rajendran
Dr. K.K. Joshi
Shri. Mohammed Koya
Dr. S. Kannappan

Food (daily menu, service)

Dr. M. Rajagopalan, Chairman
Dr. R. Sathiadhas
Dr. A.P. Lipton
Dr. Mohammed Kasim
Dr. P. Nammalwar
Dr.P. Vijayagopal
Dr. Tamilmani G.
Shri. S. Rajapakkiam
Shri. R. Seetharaman
Dr. K. Ambasankar

Stage Management

Dr. V.P. Vipinkumar (Chairman)
Smt U. Ganga
Dr. K. Madhu
Dr. B. Santhosh
Dr. P.S. Swathi Lekshmi
Shri David
Shri P.R. Abhilash
Shri Harshan
Dr. B. Santhi

Exhibition & Posters

Dr. P.C. Thomas (Chairman)
Dr. V.V. Singh
Dr. Joslin Jose
Dr. M.K. Anil
Shri Manoj Kumar
Dr. Venkataesan V.
Dr. P. Aswathi
Dr. M.A. Pradeep
Dr. Phalguni Pattnaik
Dr. V.S.Basheer
Shri. R. Ponniah
Dr. Raja Swaminathan T.S.
Dr. Margaret Muthurathinam
Smt. Hemasankari P.
Dr. Deboral Vimala

Cultural Programme

Dr. Shoba Kizhakudan (Chairman)
Smt. S. Gomathi
Smt I. Santhosi
D. Sherly Tomy

Excursion & Tours

Dr. Reeta Jayasankhar (Chairperson)
Dr. Sathyanarayan Sethi
Dr. P.K. Patil

Help Desk

Dr. Subadeep Ghosh, Chairman -
Dr. Kajal Charaborthy
Shri R. Saravanan
Shri Lovesan Edward L.
Shri G.B. Purushothama

Cloak Room

Shri Rudramurthy, Chairman
Shri S.Yuvarajan
Ms. Abitha