Empowering the marine fisheries sector with related research and development technologies - CMFRI's initiatives and plans

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Focal Points at a Glance: *The authors highlight the aspects of marine capture fisheries of India and the initiatives of CMFRI in utilising them and the production systems using cages as options for clean mariculture. The article also focusses on Satellite retrieved ocean colour data for pin-pointing fish shoals in the ocean.*

Introduction

Marine fishery resources have supplemented the protein supplies in nutrition globally and earned the status of 'cheap protein' during the past five decades. With the increased awareness about quality protein available in fish and other marine resources there has been a steep rise in demand for marine fish during the past two decades. This period witnessed a spurt in fishing efforts resulting in dwindling marine fish catches as higher exploitation rates affected sustainability. Globally, there were several instances in temperate waters where certain species and their fishery collapsed. Better diversity, higher fecundity and varied spawning peaks helped the Indian marine fishery to overcome the challenges driven by mechanised crafts in pursuit of high quantity 'cheap protein'. Even though there were peaks and falls in the inter-annual abundance of fishes that were landed along the coastal waters of India and other global fishing nations, the trends differed in their decadal growth averages. The present review examines the various aspects of marine fisheries research and development in India, the existing system of conservation research and proposes a viable alternative of production research for a carbon smart world.

Marine capture fisheries and CMFRI initiatives

With vast resources of 8,118 km long coast line, 0.53 million sq. km of continental shelf and 2.02 million sq. km of exclusive economic zone, marine fisheries in India have been playing a pivotal role in meeting the demands for fish over the years.The sector (both from capture and culture fisheries) has been one of the major foreign exchange earners, with revenue reaching Rs. 18,856 crores in 2012-13, accounting for about 18% of the agricultural export. Producing 5.42% of the world's fish, India accounts for 2.5% of the global fish market. The contribution of the fisheries sector, at an overall annual growth rate of 4.5% (6%, if aquaculture alone is considered) during the previous five year plans, is estimated at around 1.10% to the GDP and 5.3% to the agricultural GDP.

In1950, the marine fish harvest in India was 0.5 million metric tonnes. Gradually, fishing emerged as a major commercial activity due to mechanisation of fishing craft and gear and reached a production of 1 million tonnes during 1970. Bannerji and Chakraborty (1972) formulated the Multistage Stratified Random Sampling design for estimation of national marine fish landings. Data collection and their compilation based on this design started in 1970 at the Central Marine Fisheries Research Institute (CMFRI), Kochi laying the ground works for the national marine fisheries database. The database provides information on species-wise marine fish landings at all major centres in India, as well as on craft and gear used in the exploitation of the fishery, quality of craft and gear improved with technical sophistication during the period from 1970-80. With the geometric increase in the number of fishing vessels after 1970, the marine fish landings reached 2 million tonnes in 1980.

Heavy investment in harvest and post-harvest sectors in Indian fisheries during the 1980s led to further exploitation of marine resources. Marine fish landings in India reached a record 3.94 million metric tonnes in 2012. However, there were doubts about the sustainability of the marine fishery in India, resulting in initiatives such as development of stock assessment models, policy directives based on model results and enactment of legislation. But with an increasing demand for seafood (up to eight lakh tonnes valued at Rs.12,826crore as per 2011-12 estimates), the fishing effort continued to expand. Increase in the number of craft resulted in a decline in the catch per unit effort. More time spent at sea resulted in an increase in the operational cost of fishing vessels. Mechanised vessels resorted to multi-day fishing, leading to increase in unwanted by-catch and discards. There are 1,94,490 fishing craft in operation in Indian exclusive economic zone (EEZ) (Marine fisheries census 2010). The Government of India has resolved in principle to regulate the fleet size in its EEZ, according to fishery potential (UNCLOS, 1982, CCRF, 2000). The estimates of fish potential in the EEZ will set the fleet size required for sustainable harvesting. Researchers have estimated the potential of marine fisheries in India to be in the range from 2.3 to 7.46 million tonnes (Table 1) (Raghuprasad *et al.* 1970; Moiseev 1971; Gulland 1971; Prasad and Nair 1974; George *et al.* 1977; Quazim 1977; Nair and Gopinathan 1981; Mathew *et al.* 1989; Desai *et al.* 1990). A working group constituted by the Government of India revalidated the potential yield of Indian

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Table 1: Estimates of fisheries potential in Indian EEZ by various methodologies by different authors

Sl.No	Author	Estimated harvestable potential (million t)	Methodology adopted
1	Raghuprasad *et al.* 1970	11*	Primary productivity and exploitation rate
2	Moiseev 1971	3.59	Primary productivity and trophic transfer efficiencies
3	Gulland 1971	6.55	Primary productivity and trophic transfer efficiencies
4	Prasad and Nair 1974	4.60	Primary productivity and exploitation rate
5	Nair *et al.* 1973	2.30	Primary productivity to carbon
6	George *et al.* 1977	4.50	Exploratory survey, landing and review
7	Qazim 1977	7.36	Primary productivity and trophic transfer efficiencies
8	Nair and Gopinathan 1981	5.50	Primary production to tertiary carbon conversion
9	Mathew *et al.* 1989	7.46	Percentage conversion of primary production
10	Desai *et al.* 1990	3.66	Primary/ secondary production to tertiary carbon conversion
11	Working group, GOI 1990	3.90	Maximum SustainableYield (MSY) from landing; exploratory survey
12	Working group, GOI 2000	3.93	MSY; exploratory survey
13	Working group, GOI 2012	4.41	MSY and productivity estimates from PP generated from ocean colour-RS data

*Computed for the entire Indian Ocean. Estimates prior to the concept of EEZ

EEZ at 3.9, 3.93 and 4.41 mill tonnes in 1990, 2000 and 2012 respectively (Working group 1990; 2000; 2012). The various estimates differ from each other and the present production of 3.94 million metric tonnes (CMFRI 2013) implies that there is still scope for improvement.

Three approaches were adopted to estimate the marine fisheries potential of Indian EEZ (Table 1). The approaches adopted statistical and productivity methods, separately and jointly. The statistical approach provides qualitative details on distribution of marine fishery resources using fish landing data. Using ocean colour data, the productivity approach is independent of data on marine fish landings. A combination of both methods reconciles the estimates to give a value which is considered to be a reference potential for estimation of fleet size (Working group 2012). The estimate can be lower or higher than the actual potential, given the compromises made in the selection and types of the approaches.

Although it is important to have robust estimates of fishery potential as an aid to manage fisheries resources in the EEZ, so far we have been unable to arrive at figures that are widely acceptable to the experts in the field.For determining the resource stability along with the on-going intensified fishing efforts, a multi-disciplinary approach for re-assessment of resources is in vogue. There are alarming gaps for a policy planner to look upon. Prime focus on future fisheries resource research will be oriented towards building up of a spatio-temporal database on the GIS platform as a decision support tool. Numerical and time-series model data and databases from RS-GIS sources have taken a priority over real time observations. But the evident gaps in *in-situ* observation and assessment of fishery resources have to be nullified through regular survey, sampling and analysis. Automation of landing data estimation, geo-referencing of fish catches, local spawning and fishing ground delineation, resolving of physical process supporting the fishery resources, the resource vulnerability to climate change, resource economic evaluation and international trade policies impacting our resources are a few research areas to be given due attention in the next few years. With the climate change impacts making Indian fisheries sector vulnerable to forces other than over-exploitation, the ChloRIFFS (Chlorophyll based remote-sensing assisted Indian Fisheries Forecasting System) programme calls upon a thorough revalidation involving interdisciplinary efforts in marine fisheries research to point out the lacunae and set-right the contradictions between predicted and harvested resources.

Fish and fish products recorded the highest increase in price among all food commodities-transforming from a poor man's food to luxurious food item. The gross value of marine fish at the landing centre and retail level is estimated at Rs. 27,577.1 crores and Rs. 44,054 crores respectively (SEETTD, 2013). The private capital investment in fishing equipment 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 is estimated at Rs. 3,11,799 in the mechanised and Rs.17,205 in the non-mechanised sector. The percentage share of fishermen in consumer rupee (PSFCR) ranged from 40% for oil sardines to 80% for seer fish in private marketing channel. Fishing villages having Self Help Groups (SHGs) or cooperative fish marketing resulted in PSFCR which is consistently above 70% for all varieties of fish. Domestic marketing system requires more attention on modernisation, including quality control. There exists inadequate coastal infrastructure for domestic fish marketing, other than the commercial landing centers. This has led to polarisation of harbour-based infrastructure development and isolation of small centers,high level of occupational risks and also inter and intra sectorial marginalisation. 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 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 fisherwomen through capacity building interventions and training programmes
- Incentives for value addition enterprises
- Investment for coastal infrastructure development (through Public Private Partnership mode)
- Modernisation of domestic fish markets
- Special banking schemes for small scale fishery- related enterprises
- Compulsory registration of craft and optimisation of fleet size
- Sea safety measures made mandatory
- Introducing new insurance schemes focusing on the fishery sector
- Development of bio-shields, installation of early warning systems, and strengthening PFZ delivery.
- Integrated Coastal Zone Development including Responsible Coastal Tourism

Green Fishing - Fishery resources and energy efficient eco-friendly capture systems

Satellite retrieved ocean colour data (chlorophyll) can act as a surrogate for most shoaling phytoplankton feeders, especially oil sardine, off the west coast of India. Indian Remote Sensing Satellite P_4 Ocean Colour Monitor (IRS P_4 OCM) / MODIS derived chlorophyll concentration and National Oceanographic Aerospace Administration Advanced Very High Resolution Radiometer (NOAA AVHRR) derived Sea Surface Temperature (SST) images have been used to characterise the relationship between the biological (Chlorophyll) and physical variables (SST) in coastal waters and to delineate potential fishing zones. Integrated potential fishing zone (PFZ) forecasts validated by CMFRI indicated a positive Benefit Cost Ratio. Increased Catch Per Unit Effort at reduced fossil fuel expenditure (scouting time is less), can be rightly termed as 'green fishing'. But staggered forecasts due to cloud cover often inhibit the continuous predictions of PFZ. The ability of satellite based altimeters to provide data despite cloud cover and to identify the circulation features related to fisheries provides scope for filling the gap left by the traditional PFZ advisories in the presence of cloud cover. Significant fish catches occurred in areas between anti-cyclonic and cyclonic circulations where divergence occured and also between two anti-cyclonic circulations where divergence and upwelling occurred.

The spatio-temporal fluctuations of plankton richness which can be remotely sensed helps in predicting fisheries resource richness. Taking a cue from established models, patterns can be designed to predict resource availability after validation of prediction scenarios with the estimated catch from various fishing grounds. The change in the pattern of fishing, period of absence and the composition of fish caught per haul, when analysed for a range of geo-spatial expanses,will help in refining and augmenting a comprehensive prediction algorithm. Further, such models would come in handy in the assessment of marine resource potentials and their periodic revalidation on a homogenous platform with a proper measure of confidence intervals. Such exercises are of immense importance to the government and policy makers. The history of co-integrating plankton availability and resource landings were initiated at CMFRI in the early 1960s. Collaborative efforts between marine fisheries research and space applications resulted in the identification of PFZs in the 1980s. With climate change impacts making the Indian fisheries sector vulnerable to forces other than over-exploitation, the ChloRIFFS (Chlorophyll based remote-sensing assisted Indian Fisheries Forecasting System) programme calls upon a systematic revalidation and interdisciplinary efforts in marine fisheries research, to point out the lacunae and set-right the staggering contradictions between predicted and harvested resources.

Central Institute of Fisheries Technology (CIFT) has come up with green fishing systems for tropical seas. Design and construction of the 19.8 m, energy efficient, new generation combination fishing vessel with improved hull shape, bulbous bow, optimised propeller design, ducted propeller nozzle and right sized engine will lead to reduced fuel consumption. Design and development of energy saving selective fishing gear systems through material substitution will also lead to substantial fuel savings. Energy saving trawling technologies such as high speed demersal trawls, trawls for deep sea operations and large mesh semi-pelagic trawls are some other innovations in this direction.

National Fisheries Data Centre of CMFRI provides much of the supportive data for research and management in marine capture fisheries. Present estimates have only landing centre details. Proper geo-referencing of the data is required for establishing their scientific relevance. The prime focus in future fisheries resource research will be oriented towards building a spatio-temporal database on the GIS platform as a decision support tool. Numerical and time-series models have taken a priority over real time observations such as surrogate databases from RS-GIS sources and have revolutionised our research. But the evident gaps in observation and assessment of fishery resources have to be nullified through regular survey, sampling and analysis. Automation of landing data estimation, geo-referencing of fish catches, local spawning and fishing ground delineation, resolving physical processes supporting the fishery resources for better understanding of the resource vulnerability to climate change, resource economic evaluation and international trade policies impacting our resources are research areas to be given due attention in the next few decades in order to augment the fisheries resources and sustain their exploitation.

Sea food export from the country is a major FOREX earner. But with the imposition of quota regulation measures on account of proper fisheries management, there is a necessity to rightly geo-reference fish landed without any duplicity in their entire supply-chain. Subsidy supports to exports invite countervailing duties. It is imperative to divert the subsidies provided in support of sea food exporters to sector based infrastructure development so that capital intensive works will augment export earnings. If we need to rightly utilise the money, a geo-referenced data base on existing infrastructure is required. Further, data on the quantum of earning per landing centre is essential while diverting the funds. GIS databases on such information are essential in the context of quota regulations, subsidies and issues on countervailing duties for sector based funding.

Climate resilience in fisheries- Vulnerability assessment *vis-à-vis* Adaptation strategies

Climate change is one of the biggest global challenges facing mankind and governments are looking for practical and time-bound strategies and plans for their mitigation and adaptation. Understanding the impacts of climate change and natural hazards is critical for developing adequate risk management strategies. Coastal vulnerability describes the susceptibility of the natural system and of coastal societies (persons, groups or communities) towards coastal hazards. It is a condition resulting from a system's social, economic and ecological properties and is a function of its natural and social coping and adaptive capacity to adverse impacts, namely its resilience. Assessing coastal vulnerability is an important prerequisite to determine areas of high risk, why they are at risk and what to do to reduce the risk. The climate change effects have multidimensional impacts on environment, fishery, social, economic and development drivers. The perception of the primary stakeholders- fishing communities, plays a major role in proactive participation in disaster management, adaptation and mitigation plans. The development of the conceptual framework progressed with identification of the coastal districts and villages based on the different environmental, fishery and socio economic parameters.

CMFRI implemented the PARS methodology - Parameter, Attribute, Resilient Indicator and Score, a conceptual framework developed for assessing the climate change vulnerability of coastal livelihoods to prioritise and rank the different impacts as perceived by the fishers. The fishers' perception on climate change effects revealed that fishery was the most impacted parameter followed by economic and environmental impacts. Social impact is the least impacted parameter as perceived by the fishers. The study indicates that the long term effects of climate change are not realised/perceived among the fisher households. Fishers perceive that the fishery and economic parameters are of importance in the climate change adaptation and mitigation plan.The level of awareness is minimal which indicates that the fishers could not correlate environmental changes consequent to climate change to their livelihood. The fishers are prone to loss in fishing days due to erratic monsoon. The work done by CMFRI suggests the immediate need to improve on the awareness of the primary stakeholders' knowledge with respect to climate change by involving them in the disaster preparedness, management and mitigation planning and implementation process. Researchers at CMFRI are working on chlorophyll dynamics and fish productivity in a climate change regime, simulation models for forecasting climate change effects, species vulnerability due to climate change, database development and ocean acidification/ climate change issues on marine resources.

Conserving the blue carbon ecosystems

Green technologies and blue carbon have been the buzz words during the last two decades for many organisations working on marine sciences and related aspects. Blue carbon is the carbon captured by the world's oceans and coastal ecosystems. The carbon captured by living organisms in oceans is stored in the form of biomass and sediments from mangroves, salt marshes and sea-grasses. A front runner in marine fisheries research in India with set global standards, CMFRI has invested heavily in its research on greener technologies for marine fisheries sector and contributed to improving/sustaining the blue carbon resources. With a prominent role in carbon sequestration and storage, the various activities related to our marine ecosystem often are of comparable/higher efficiency than their terrestrial counter parts. Since the 1950s, CMFRI has had a vision steered by global and national leaders in rightly sustaining the production related process in improving the fish catch (marine fish capture as well as mariculture) and conserving the blue carbon ecosystems like tidal marshes, mangroves, coral reefs and sea-grasses along the coastal waters of the northern Indian Ocean. These research findings have been utilised globally for managing tropical coastal marine resources.

Sustaining/rebuilding the marine ecosystems; tidal mudflats, wet-lands, mangroves, marshes, estuaries, beaches, lagoons and coral reefs; have also become a prime responsibility in marine fisheries management. Along with the fishing pressure there is a concern for habitat degradation also. CMFRI, for the last six decades, has contributed immensely to biodiversity conservation and continues to do so. A major activity by CMFRI in this direction is with respect to artificial reefs.

Artificial reefs will reduce unwanted fishing as trawl operations in such areas will result in severe gear damage. Under Indian conditions,the best measure is to deploy the artificial reefs along inshore areas at 20 m depth contours. Artificial reefs are triangular concrete structures/ modules deployed to the bottom of the sea bed. They provide shelter to brooder fish and juveniles. They also offer surface areas for attachment of eggs after spawning. Thus, we can protect the nursery grounds of fishes by installation of artificial reefs and thereby enhancing the recruitment of commercially important species. Deployed artificial reef areas become unfit for trawling operations rendering the area as a natural "Marine Protected Area" (MPA) thus protecting the biodiversity, habitat and brood-stocks. Healthy brood stock of fishes will be a spawning stock biomass for supplying young fish to the fishing areas on a sustainable manner (recruitment).It is emphasised here that the major aim of marine fisheries management is mainly to sustain the fisheries with limited scope to increase production by at least 1% cumulatively in the next 35 years (by 2050).

CMFRI, in association the Govt of Tamil Nadu, has deployed the artificial reefs in coastal waters near 50 villages resulting in the enhancement of traditional fisheries by 2 to 5 times over the last ten years. Consequently, there is an increase in demand from the traditional fisherfolk to install more artificial reefs in Tamil Nadu. This example can be taken as a national model for creating more of awareness among the fisherfolk in other States and for conducting awareness training programmes. Each module cluster cost Rs. 30 lakhs and is sufficient for 1 km. If the entire coastal line is provided the same impetus over a period of at least next 10 years, costing Rs. 10,000 crores, the marine fish catch is likely to reach at least 6 million tonnes by 2050.

Production systems using cage as options for clean mariculture

CMFRI has undertaken the large scale demonstration of open sea as well as backwater cage culture in most of the maritime States of India. The technology is purely indigenous and highly economical and sustainable. It is very easy to adopt. Capital investment for a 6 m diameter circular cage in the sea is about Rs. 3 lakhs initially, including the cost of cage frame, nets, mooring, seed and feed. By adopting culture of high value species, the production of 3-5 tonnes/ cage can be attained with an economic return of Rs.6 to 10 lakhs per harvest, spread over a period of 6-8 months depending on the species. The life of a cage frame is above 5 years. The MoA/NFDB have recognised this as a government scheme eligible for 40% subsidy and the technology is gaining lot of popularity among coastal fisherfolks. Seed inputs are abundantly available along the coast and fisher folks are skilled in collecting them. The feasibility of several species emerging as candidate species for cage culture is due to the on-going breeding programmes and their possible collection from the sea may be discontinued in the long run. Similarly, there are about 5 large feed mills in Andhra Pradesh with high production potential for manufacturing suitable feed for marine fish.

CMFRI's grow-out experimental feed for Pompano, based on feed formulation produced commendable results. Results of this study indicated the highest observed omega-3 fatty acid composition (16.98%) in the fish meat fed by this feed. Hence, the feed is not only available on demand but also is efficient in the fish meat quality it produces. Similarly there are millions of hectares of low lying saline areas which are not utilised and can be brought under mariculture with suitable incentives from the government/NFDB. CMFRI has established the first Recirculation Aquaculture System (RAS) laboratory in India and marine fish brood bank in these RAS acts as a model for establishing some more RAS in public sector to maintain the quality and quantity for sustainable seed production. The goal is production of fertilised eggs/ first day larvae and their supply to the hatcheries at a nominal cost, so that private hatcheries can raise them further and deliver them to the needy farmers at a price. Marine fish brood stock maintenance is complicated and risky. Hence, private entrepreneurs may not be enthusiastic in marine fish seed production. Further, a regulation of fish seed production under public sector also ensures quality seed production.There are initiatives in basic research in marine biotechnology for improved feeds for fishes including ornamental fishes, bio-prospecting, diseases surveillance and stock identification also.

Conclusion

Sustainable fisheries management options, if implemented properly, indicate possible enhancement of harvestable potential in Indian EEZ to a possible extent of 6 million tonnes or more. Opportunities in open sea cage culture and related developments in the field of mariculture during the last 5 years show a way forward in open sea mariculture practices and propose a production ideal to the tune of 4 million tonnes in the coming years from mariculture sector alone. High mariculture production in countries like China is due to production of sea weeds and molluscs,but, the Indian sea food market comprises mainly of fin fishes of edible standards. If properly implemented, there are possibilities that the marine fish production may be enhanced to the tune of 10 million tonnes (6 million tonnes from capture and 4 million tonnes from mariculture) by 2050. The present review reiterates the need to revalidate the on-going management measures scientifically and pragmatically to enhance the marine fish production in a sustainable manner.