...Way forward for enhancing Indian Marine Fish Production

— *With Developmental Measures Suggested for Adoption*

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Focal Points at a Glance

Dwelling on the limitations in the Management of Marine Fisheries of India, the author highlights certain areas of further research for eventual adoption of the results for promoting Indian marine fish production. These include a). Artificial reefs, b). Remote sensing based fisheries forecasting, c). GIS based marine fisheries management and d).Cage culture.

Introduction

World population is increasing, rendering shrinkage of arable land. Therefore, package of practices followed in the agrarian sector is for vertical expansion of productivity. Over the last few years, the ideas on a carbon smart and health conscious world propagate a holistic view of organic cultivation, which promotes a qualitative production of food. Coastal plains and riverine valleys used to be well known for food production. In the realms of climate change there are issues of Mean Sea Level rise, saline water inundation and various related issues rendering much of these productive lands unavailable for agriculture. Even with stringent regulations, most of these lands are converted into residential areas affecting the equations with respect to food production. Various researchers suggested that in the years to come, globally people will have to look at the seas for food. To meet the requirement of fish by 2050 *vis-à-vis* the population, at current level of management and restrictions, there seems to be much more dependence on marine fisheries sector to be exercised for livelihood.

During the last two decades global demand of sea food has increased substantially. But there were classical conservation thoughts which led to reduced exploitation of sea food resources. Rather than production enhancement, conservation and sustainability were coined as prime areas of marine fisheries research. Globally marine fisheries research took away chunk of its research grants and schemes for promoting the concerns on fisheries, keeping the production at stake. But there are various schools of thoughts now realising that it is not just the sustainability but enhancement of production within the ambits of conservation, which is essential to plan for future.

Being one of the biggest marine fisheries producing countries in the world (Table 1), coastal waters of 9 maritime States and 4 Union territories in India are managed as State/UT subjects as part of the territorial limits of the sea.

Marine fisheries management in India followed the global trends, despite the fact that there were no instances of a collapsed fishery here unlike the temperate waters where operational fisheries collapsed several times due to various factors. Similar concerns and situations simulated for Indian marine fisheries created a school of thought redeeming marine capture fisheries research *per se* to a conservationist mode relying more on sustainability neglecting many a time the possible production process. The present review calls upon the various aspects on marine fisheries research and development, critically examining the existing system of conservation research and proposes a viable alternative of production research for a carbon smart world.

Capture fisheries scenario

Marine resources off Indian shores have been exhibiting thorough heterogeneity and complex inter-relationships over years. The catch rates over the years have thrown up intriguing phases which defy common established logic (Fig. 1). The contribution of marine fishery sector during pre-independence period was limited to 0.5 million metric tonnes only. Fisheries, emerging as a thrust sector from subsistence to mechanisation with new fishing crafts and gears during post-independence era, propelled the research initiatives on estimation of resource-wise marine fish landings. Pilot studies by Bannerji and Chakraborty (1973) during the early 1950s and till 1970s over a span of two decades established the Multi-stage Stratified Random Sampling Design for building up a time-series database on season-wise, gear-wise and species-wise marine fish production.

National Marine Fisheries Data Centre (NMFDC) is instrumental in managing the database generated Fishery Resources Assessment Division of CMFRI since its inception. Food and Agriculture Organisation has been involved in compilation of similar data sets globally for different nations depicting the global trend.

The harvest of marine fishery resources doubled from a subsistence level of 0.5 million tonnes during 1950s to 1 million tonnes during 1970 as a result of research interventions. With the advent of gears and crafts in a geometric progression during the 1970s, resource assessment studies started radiating signals of potential dangers involved in unregulated fishery and management of Indian fisheries, which triggered new initiatives in resource assessment research. Estimated marine fish landings indicated an increasing trend in the marine fish production reaching 2 million tonnes by the beginning of 1990s and increasing steadily afterwards (Fig. 2). For establishing a sustainable and enhanced productivity from Indian Seas there were lot of initiatives in the 1970s for rightly predicting the resources, regulating the fishery, introducing policy directives, enactment of legislations and development of stock assessment models for the diverse fishery in Indian waters. Heavy investment in harvest and post-harvest sectors in Indian fisheries during 1980s rendered vulnerable, exploitation of many marine resources. Landing to the tune of 3.06 million metric tonnes, a record reckoning

Table 1: A profile on marine fisheries of India, 2010*

Component	Profile
Physical Component	
Length of coastline	8,129 km
Exclusive economic zone	2.02 m km^2
Continental shelf	0.50 million km^2
Inshore area (< 50 m depth)	0.18 million km^2
Fishing villages	3,288
Human Component	
Marine fishers population	3.9 million
Active fishers population	0.9 million
Infrastructure Component	
Landing centers	1,511
Major fishing harbours	6
Minor fishing harbours	38
Mechanised vessels	72,559
Motorised vessels	71,313
Non-motorised vessels	50,618

***Note : Based on Marine Census 2010**

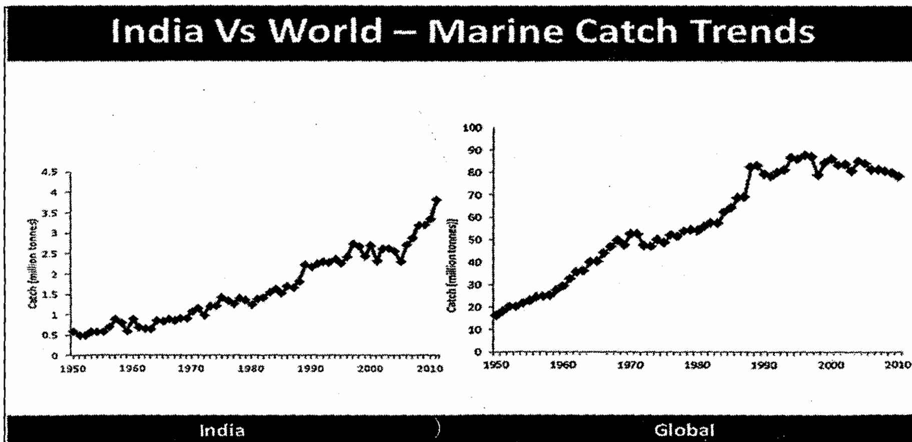

Fig.1: Fish production trends during the last seven decades in Indian (CMFRI) as well as global marine capture fisheries (FAO)

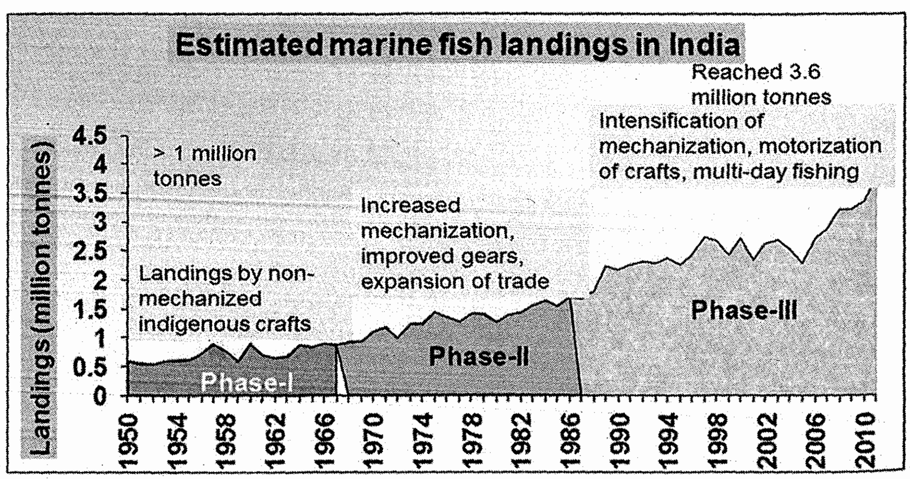

Fig. 2: Fish production trends during the last seven decades in India (CMFRI) with the three different phases of sectorial expansion

achievement was ensured by the end of this phase.

Total catch is an important indicator to monitor and assess the status of the fishery. The decline in the catch is a signal for appropriate interventions from the managers. Annual growth rate in marine fish production on a decadal average scale indicate that there has been a steady increase in marine fish production in the coastal waters of India. But globally the production has been in a retrogressive phase (Fig. 3). There is a biological contrast in the fish available in Indian waters too. Unlike the abundant single species fish stock biomass of nearly 50% replenishing the fishery in temperate waters; most of the multispecies fishery in the coastal waters of India is supported by fishes with high fecundity, continuous spawning ability, protracted spawning season and faster growth rates.

Limitations of Marine Fisheries Management in India

Generally fishery managers opt to say that Indian fishery is managed as an open access fishery. On the contrast, Indian marine fishery is regulated but with different management options suiting to the area of fishery with some limitations. The following reasons are attributed to limitations in marine fisheries management research and operations in the coastal waters of India:

a)Stock assessment models devised for marine fisheries management fail at operational level: In an open access natural resource, a fishery is rarely optimally allocated leading to economic inefficiency and overfishing. Dynamic bio-economic models provide a suitable platform for solving these issues. But theoretical models often fail to become operational. With multi-species and multi-gear operations being carried out, there is no mechanism to implement the management of results obtained using stock assessment models. Further, the models devised for temperate waters fail to establish the ground realities in tropical countries. These models utilise the growth parameters estimated by length frequency method. Total mortality is estimated by length converted catch curve method and natural mortality by the empirical relationship derived by Pauly (1980).Natural growth rates often are better than the predicted rates where life of fish is short spanned as in most tropical fishes. Incorporation of laboratory tested growth rates based on individual species into assessment models can produce better results.

b) Ecosystem based management of marine fisheries with more complexities and input data requirement: Intricacies of ecosystems always remained a passion for researchers to unveil the probable outcomes of biotic and abiotic factors affecting its progression. Anthropogenic and related activities disturbed a smooth flow of ecological progression and resulted in repercussions from nature. Despite the ingenious curiosity, ecological and ecosystem models started producing a new trend in the decision making mechanism of management of natural resources. Simulated pictures showing the possible outcome of prevailing activities and enormous amount of data generated during the modeling process evoked a sense of eco-friendly approach in the management of natural resources. Marine ecology, being a conglomeration of still more elements in its own emerged as a focused area of research in the last two decades. Mathematical tools aided with software assistance paved the way for a breakthrough in the assessment and evaluation of marine ecology. But most of these numerical

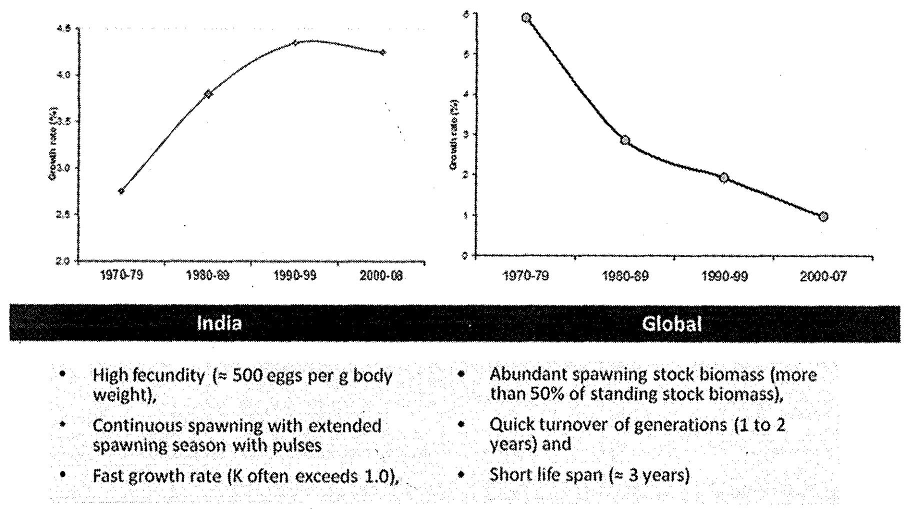

Fig. 3: Decadal averages depicting the trends in marine fish production during the last seven decades in India (CMFRI data) and World (FAO data)

Table 2: Seasonal fishing regulations along the maritime States of India

State/Union Territory	Year of introduction	Notified period	Days	Type of fishing banned	Type of fishing permitted
Gujarat	1998-99	10 June – 15 August	67	All craft	Nil
Maharashtra	1990	10 June – 15 August	67	All craft	Nil
Daman & Diu		1 June – 15 August	75	Trawlers, gillnetters and dol netters	Motorised and traditional craft
Goa	1989	10 June – 15 August	67	All craft	Nil
Karnataka	1989	15 June – 10 August	57	All except motorised OBM/IBM vessels upto 25 hp engine	
i) Dakshina Kannada					
ii)Uttara Kannada		15 June – 29 July	45		Motorised upto 25 hp engine
Kerala	1988	15 June – 31 July	47**	Mechanised vessels/motorised craft>10 hp engine	All traditional and motorised craft of OBM/IBM up to 10 lrp engine
Tamilnadu and Puducherry	2001	15 April – 31 May	47	Mechanised fishing/trawlers	All non motorised and motorised craft with less than 25 lrp engine
Andhra Pradesh	2000	15 April – 31 May	47	Trawlers and motorised craft with>25 hp engine	Traditional and motorised craft <25 hp engine
Orissa	2000	15 April – 15 June	60	Trawlers and motorised craft with>25 hp engine	Traditional and motorised craft <25 hp engine
West Bengal	1995	15 April – 31 May	47	Trawlers, gillnetters, behundi nets, bir net	NA

Subject to year to year change; **61 in 1988 & 67 in 2006; NA – Not Available
Source: Vivekanandan, et.al., 2010

models have high dependence on input data, as enormous and complicated as the ecosystem being studied. The outputs of these models are highly subjective and not implementable on an operational scale. The end results often restricts on a qualitative inference confirming existing results. With the advent of satellite oceanography and information communication technologies ecosystem based management of marine fisheries remains a possibility but not an operational concept for the entire Indian fishery resources.

c)Fisheries management as a State subject lacking coherence in uniform regulations: Developmental departments in all States and Union territories of India manage the fisheries for the territorial waters under their jurisdiction which often tend to become an ineffective and inefficient mechanism of implementation due to their own jurisdictional limitations. One of the major management measures adopted in India is the seasonal ban on mechanised fisheries for 45 days or more both on east coast and west coast with different timings. However, the fishing by non-mechanised fisheries is allowed. The regulations followed vary from State to State and not implemented coherently. Thus, this has limited impact on conservation.

Table 3: Recommended Minimum Legal Size (MLS) and Minimum Legal Weight (MLW) of marine resources of India (Pillai et al., 2009)

Species	Common name	MLS (cm)[a]	MLW (g)[a]
CEPHALOPODS[b]			
Uroteuthis duvauceli	Squid	8	25
Sepia pharaonis	Cuttlefish	11.5	150
Octopus membranaceous	Oclopus	4.5	15
LOBSTERS			
Panulirus nomarus	Rock Lobster	-	200
Panulirus polyphagus	Rock Lobster	-	300
Panulirus omatus	Rock Lobster	-	500
Thenus orientats	Sand lobster	-	150
FINFISHES			
Sardinella longiceps	Oil sardine	14	-
Rastrelliger kanagurta	Indian mackerel	16	-
Euthymus affinis	Little lunny	40	-
Auxis hazard	Frigate tuna	30	-
Katsuwonus pelamis	Skipjack tuna	44	-
Thunnus abacares	Yellowfin tuna	70	-
Decapterus russelli	Scad	14	-
Megalaspis cordyla	Horse mackerel	22	-
Trichiurus lepturus	Rbboonfish	56	-
Scomberomorus commerson	King seer	75	-
Nemipterus japonicas	Threadfin bream	14	-
Nemipterus mesoprion	Threadfin bream	12	-
Cynoglossus macrostomus	Sole	11	-
Lactarius lactarius	Whitefish	13	-
Epinepheleus lauvina	Grouper	72	-
Parasromateus niger	Balck pomfrel	30	-
Pampus argenteus	Silver pomfrel	-	200

*based on length-al-first malurity,, MLS of cephakpods in based on the smallest observed manile length of mature specimens

d)Limitation on a scientific estimation of harvestable yield for marine fisheries of India: Assessment of marine resource potential off Indian EEZ has been a vital task to be carried out before crucial planning interventions of the government. Apart from fin and shell fishes, the marine domain is peppered with many biota which have direct and indirect role in deciding the potential of the EEZ. As the resource domain and its actual extent of spread is an unknown entity, predictions based on indices obtained on shore have played a major role in reassessing the marine resource potential. Based on theoretical considerations, marine fisheries potential were estimated at the aegis of union government based on the National Fisheries Data Centre data of CMFRI. Although this data base is based on multistage stratified random sampling method (which is an internationally accepted estimation procedure for marine capture fisheries of India.) this necessitates the need for a pragmatic estimation procedure for establishing the harvestable marine fisheries potential of Indian EEZ.

e)Lack of integration of data base on individual species into a multi species management scenario: Indian marine fisheries being a multi-species and multi-gear effort, it will be ideal to have a decision support tool which can integrate the database on individual species into a holistic one for operationalising the fisheries management. But most of the models working on Indian marine fisheries sector tend to limit it to information till species level. The data support for most of these models are from a post-mortem analysis of fish landed from the coastal waters. They fail to examine the real *in situ* production process supporting the fishery.

f)Mesh size of gear – recommendations vs implementation issues: Various recommendations for the mesh size to be followed for different fish species are in vogue. According to these the fine meshes of gears like trawls and bag nets cause large-scale destruction of juveniles of many fishes. There were recommendations on Minimum Legal Size (MLS) for different categories (Table 3). But these recommendations fail to become operational due to the multi-species, multi-gear fishery existing in the coastal waters of India. For a biological management system to be effective, monitoring and surveillance are necessary, which turn out to be very expensive.

g)Fleet strength- pragmatism over-ruling diminution of fleet size: The Indian marine fisheries are characterised by about 2,000 varieties and caught mostly by mechanised trawlers, purse seiners, gillnetters and long-liners apart from several mechanised and non-mechanized small boats. However, in western temperate countries the marine fishery is mainly constituted by a few large varieties of fish, managed under quota system unlike ours. In spite of several management measures western fisheries often face crisis and crash periodically. In India the marine fishery are characterised by 0 to 3 year class fishery with more generation turn over are caught by multi-species gears making it very difficult to postmanage in spite of processing huge scientific data over the years.

When compared to the world fisheries scenario the Indian marine fisheries are still showing upward trend in total catches and catch rates. The common fisheries management method of imposing an upper limit on the Total Allowable Catch (TAC) by restricting the number of vessels also has short comings. Fishing capacity of the crafts can be enhanced using new designs that satisfy the restrictive rules, and by including new fishing devices and efficient gears. Hence, license restriction or TAC also fails to impress upon as an effective management measures.

h)Ban on fishing and protected areas are logically assumed regulations without a deterministic model: Indian marine fisheries are managed similar to wildlife with closed areas- 31 marine protected areas and 33 marine national parks and sanctuaries (Singh, 2003) and closed seasons- (trawl / fishing ban) being practised widely for regulating the fishing pressures. But with respect to the gear and craft, there are few recommendations for regulating their usage in coastal waters. Fishing reserves will not work for migratory species. Location of fishing reserves are often dubious and the spawning aggregations, nursery and spawning grounds of all major species should be studied before enacting regulations on marine protected areas. All the fish in the sea lay eggs which will be drifted close to the coast where the depth of water is less than 20m. Coastal areas are the best nursery ground for the larvae that come out of these eggs as these areas are highly productive and rich with planktonic food essential for their survival and sustained growth. After attaining the juvenile stage, fishes migrate to their habitats. Hence any fisheries management must address the protection of the nursery areas during spawning time and habitats during maturation phase for sustaining the fisheries.

There are limitations on the existing marine fisheries management measures as discussed above and these limitations invoke the need for novel methods to reduce fishing pressure but enhance the production using sustainable measures of management. A few management options are discussed below.

Way forward

For augmenting the production from marine fisheries sector, interventions are required in the following areas of research on a contingent basis:

i).Artificial Reefs: 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 on habitat degradation also. Artificial reefs will automatically reduce unwanted fishing as crafts like trawlers cannot operate in areas of artificial reefs as trawl operations in such areas will result in severe gear damage.

Under Indian circumstances the best measure is to deploy the artificial reefs along inshore areas around 10-20m depth contours. Artificial reefs are triangular concrete structures/modules deployed to the bottom of the sea bed (Figure 4). They provide shelter to brooder fish and juveniles. They also offer surface areas for attachment of eggs after spawning. The major seed resources like seer fish, mackerel, tuna etc., are available only at shallow depth of less than 10 m. Thus, we can protect the nursery grounds of these fishes by installation of artificial reefs and thereby enhancing the recruitment for the entire Indian EEZ. Deployed artificial reef areas become unfit for trawling and purse seine operations rendering the area as a natural "Marine Protected Area" (MPA), thus protecting the biodiversity, habitat and brood-stocks./Healthy broodstock of fishes will be a spawning stock biomass for supplying young fish to the fishing areas in 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 with the Government 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 increased demand from the traditional fisherfolk to install more of artificial reefs in Tamil Nadu. This example can be taken as a national model for creating more of awareness among the fisher folk in other States and for conducting awareness training programmes. Each module cluster may cost about Rs 30 lakhs and is sufficient for about one km. If the entire coastal line is provided with 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.

ii). Chlorophyll based Remote Sensing-Assisted Indian Fisheries Forecasting System (ChloRIFFS): Heavy investment in harvest and

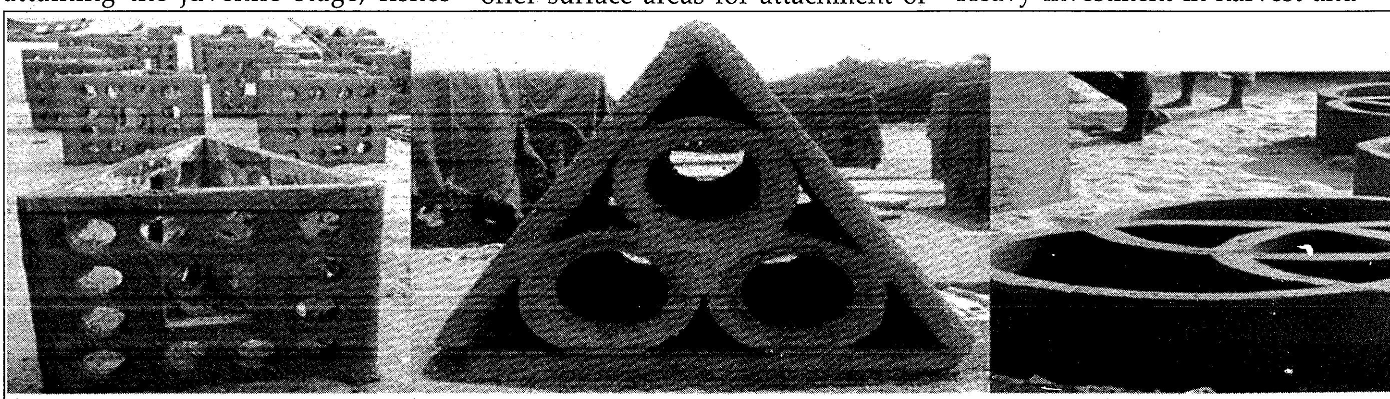

Fig 4: Three types of modules 70 each from a cluster, occupying 1000 m^2 area, with about 500 m^3 volume and offering about 3000 m^2 surface area for attachment

harvest sectors in Indian fisheries during 1980s rendered good exploitation of many marine resources. Landing to the tune of 3.06 million metric tonnes, a record reckoning achievement, could be ensured by the end of this phase, but with an alarm on the sustainability of the fishery. Researchers are wavering from values ranging from a few lakhs to 11 million t for the estimated marine fish resource potential of India (Raghuprasad, 1970), and hence there is a need for a comprehensive revalidation of the earlier exercises. Present production values recording new heights close to 3.94 million tons indicate that the Indian marine fishery has still more potential as indicated by Raghuprasad (1970).

In the changed regime where climate driven forces are prevalent influencing the resource stability along with the on-going intensified fishing efforts a multi-disciplinary approach for re-assessment of resources has come into 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 in 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 process 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 few focused research areas to be given due attention in the next few years to augment the fisheries resources and sustain their present level of exploitation.

Towards establishing a scientifically deduced relationship between the marine environment and the resource availability on a realistic basis, there is a need for a focused application of established easy surveillance of oceanic, geophysical and physic-chemical parameters and their direct or latent influence upon the plankton which happens to be the self-replenishing source of food and nutrition for the fishery resources spread in our EEZ. The spatio-temporal fluctuations of the plankton richness which can be remotely sensed have long been established as a major factor in predicting fisheries resource richness. Taking cue from these established models, patterns can be designed to predict the resource availability from the easy-to-observe parameters after a thorough validation of the prediction scenarios put together 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 would help 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 interval. 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 since the early 1960s. Collaborative efforts between marine fisheries research and space applications resulted towards the identification of potential fishing zones (PFZ) in the 1980s and 1990s.

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 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.

iii).GIS based marine fisheries Management for increasing production and conservation of biodiversity: Most of our fisheries management options are temporal in nature without giving much thrust on the spatial component. Ever since fishing has emerged as an industry, operating far and wide from the operating centre, the spatial information on the fishing ground became an essential component to come out with precise regional implementable policies in fisheries management. Even though the importance of spatial analysis of fishery data for better management of the fishery was known for long, the spatial data collection was not affordable during the past days and equipments like GPS were rare in use. Now GPS is available with all commercial fishing fleets and getting spatial data is as easy as getting the fish samples for analysis and more over GIS technology was developed in all sorts of terrestrial applications, and in marine applications also the technology is in ready to use form. Geographical Information Systems (GIS) combined with other analytical tools and models permit improved spatial management which can provide various dimensions to the data analysis.

One of the major reasons for stagnation of marine fisheries production has been attributed to the high degree of juvenile exploitation, especially in trawl fisheries. Mostly the juvenile catches are incidental, which is mainly happening due to the lack of information on the seasonal spatial distribution of juveniles and adult fishes. It was found that reduction of juvenile exploitation had been enhancing the fish production in subsequent years. In recent years 20 to 30% of the trawl landing in India is constituted by juveniles of commercial species and it is estimated that a reduction of 10% of juvenile landing from the present level can increase the fish production in subsequent years at least by 20%. For understanding the distribution of juvenile and adult population in the fishing ground, GIS will be a reliable tool, which will help researchers to suggest operational restrictions to reduce juvenile fishery and thus can contribute to the increase in marine fisheries production. GIS can be an efficient tool for decision making in the declaration of marine protected area (MPA) and essential fish habitats (EFH) on the basis of qualitative and quantitative assemblage of juveniles or spawners in particular geographical area and GIS also will be a reliable tool for finalising the sites for artificial reef installation for biodiversity conservation. From fishery biology point of view, time bound studies in selected fishing grounds can reveal the biological characteristics of resident taxa like, *in situ* growth, *in situ* mortality, measure the effect of fishing pressure, spawning area, spawning period, larval, juvenile and spawning and feeding migrations.

In the era of green fishery and in terms of reduction of CO_2 emission in marine fisheries sector, time series GIS based information collected on the fishery distribution is of paramount importance. In the present marine fishing scenario, 10 to 25% of fuel is being spent on searching of desirable variety of fishes. This is leading to considerable amount of CO_2 emission in fishing sector and also increasing the expenditure per kg of fish production. Analysis of GIS-based time series data will enable to predict the fishing ground for various fishes and seasons of their abundance with high degree of precision. Such interventions will be of great help for the fishermen in reducing the searching time for the recourses seasonally, thus improving their economy and also helping in protecting the environment by reducing CO_2 emission considerably. Application of GIS can provide illustrative proof, which in turn will enable the policy makers to convince stakeholders regarding the scientific basis of policy interventions. The data base when created on GIS platform with illustrations in the form of maps will work as a tool for the policy makers to find mutually agreeable solution to tackle problems in conserving and managing the fishery with the active participation of all stakeholders.

iv).Cage Culture for reducing fishing pressure, improving livelihood in coastal areas and increasing fish production: 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 for adoption. 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 valued species the production of 3-5 tonnes/ cage can be attained with an economic return of 6 to 10 lakhs per harvest, spread over a period of 6-8 months depending on the species. The life of cage frame is above 5 years. Since the Ministry of Agriculture/National Fisheries Development Board have recognised this as a government scheme eligible for 40% subsidy, the technology is gaining lot of popularity. The inputs are abundantly available along the coast and fishers are skilled in garnering them. Feasibility of several species emerging as candidate species for cage culture due to the ongoing breeding programmes, the possible collection from the sea may be deemed to be sustainable 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. Recent research findings from CMFRI's grow-out experimental feed for Pompano based on feed formulation by the company, produced commendable results. Hence, feed is also not a limiting factor. Similarly there are millions of hectares of flow-oriented saline areas which are not utilised and can be brought under mariculture with suitable incentives from the government/ NFDB. CMFRI has established the first Recirculating Aquaculture System (RAS) laboratory in India and a National marine fish brood bank. This will serve as a model for establishing some more brood banks in public sector to maintain the quality and quantity for sustainable seed production. The approach is for 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 broodstock 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.

Conclusions

Sustainable fisheries management options, if implemented without fallacies, indicate possible enhancement of harvestable potential in Indian EEZ to a possible extent of 6 million t or more, than reducing it. 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 tons in the coming years from mariculture sector alone. High mariculture production in countries like China because of is production of sea weeds and molluscs. However, Indian sea food market is related to finfishes of edible standards. If properly implemented, there are possibilities that the marine fish production may be enhanced to the tune of 10 million t (6 million t from capture and 4 million t from mariculture) by 2050. The present review calls upon the need to revalidate the ongoing management measures scientifically and pragmatically to enhance the marine fish production in a sustainable manner.

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