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Green Technologies in Marine Fisheries for Sustainably Exploiting and Conserving the Blue Carbon - CMFRI Initiatives and Accomplishments

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Green technologies and blue carbon has been the buzz word during the last two decades for many organizations working on marine sciences and related aspects. A front runner in marine fisheries research in India with set global standards, Central Marine Fisheries Research Institute has invested heavily on its research on greener technologies for marine fisheries sector and contributed in improving or sustaining the blue carbon. With prominent role in carbon sequestration and storage, the various activities related to our marine ecosystem often led to comparable or higher efficiency than their terrestrial counter parts. Since 1950s, CMFRI 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 northern Indian Ocean. These research findings have been utilized globally for managing tropical coastal marine resources. In the context of the International symposium on 'Greening Fisheries - Towards Green Technologies in Fisheries' organized by SOFTI and CIFT, India, this souvenir article touches upon the various aspects on green technologies in marine fisheries research and development examining the existing system of conservation research and proposes a viable alternative for a carbon smart world.

Fishery resources and energy efficient eco-friendly capture systems

Remote sensing based chlorophyll data (primary production), retrieved for the coastal waters along the southwest coast of India during the upwelling bloom, can be positively correlated to oil sardine ladings during upwelling event. 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 characterize the relationship between the biological (Chlorophyll) and physical variables (SST) in coastal waters and potential fishing zones are delineated. Integrated potential fishing zone (PFZ) forecasts validated by CMFRI indicted the positive Benefit Cost Ratio in using the predictions. Increased catch per unit effort at less fossil fuel expenditure, as 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 also 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. Initial studies reveal significant catches occurring in areas between anti-cyclonic and cyclonic circulations where divergence occurs and in areas between two anti-cyclonic circulations where divergence and upwelling occur.

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 and the composition of fish caught per haul, when analyzed 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 potential 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 in the identification of potential fishing zones (PFZ) in the 1980s and 90s. 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.

National Fisheries Data Centre of CMFRI is the major 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 the scientific relevance. 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 revolutionized 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 a due attention in the next few decades to augment the fisheries resources and sustain their present level of exploitation.

Seafood export from the country is a major FOREX earner. There is a necessity to rightly geo-reference fishes landed, without any duplicity, in their entire supply-chain. Subsidy supports to exports are inviting countervailing duties. It is imperative to divert the subsidies provided in support of exporters to sector based infrastructure development so that capital intensive works of this type will augment the export earnings without any issues on countervailing duties. If we need to rightly divert the money, a geo-referenced database on existing infrastructure is required. Further, the quantum of earning by the relevant sites also is essential while diverting the funds. GIS databases on such relevant information are essential in the context of quota regulations, subsidies and issues on countervailing duties for sector based funding.

Conserving the blue carbon ecosystems

Sustaining and rebuilding the marine ecosystems such as 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. CMFRI for the last 6 decades has contributed immensely on biodiversity conservation and continues to do it. A major activity by CMFRI in this direction is with respect to artificial reefs.

Artificial reefs will automatically reduce unwanted fishing, 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 20 m depth contours. Artificial reefs are triangular concrete structures deployed at 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. The major seed resources like seerfish, mackerel, tuna and the like 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 entire Indian EEZ. Artificial reef areas becomes 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 brood stock of fishes in such areas will facilitate recruitment. It is emphasized here that the major aim of marine fisheries management is 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 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 in demand from the traditional fisher folk to install more artificial reefs in Tamil Nadu. This example can be taken as a national model for creating more awareness among the fisher folk in other states. Each module cluster may cost about Rs 30 lakhs and is sufficient for about 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 t by 2050.

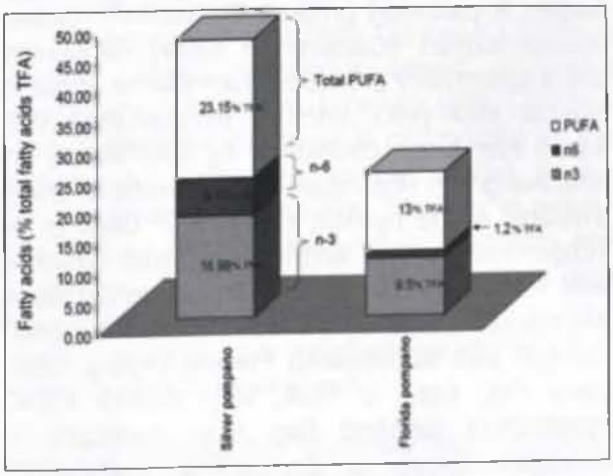
Vagaries of climate change in fisheries-vulnerability assessment vis-à-vis adaptation strategies

Climate change is one of the biggest global challenge facing mankind and governments are looking for practical and time-bound strategies and plans for its mitigation and adaptation. Vulnerability has emerged as a central concept for understanding the impacts of climate change and natural hazards and for developing adequate risk management strategies. Coastal vulnerability describes the susceptibility of the natural system and of coastal societies 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 where there are 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 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 district, villages based on the different environment, fishery and socio economic parameters. CMFRI focused on Parameter, Attribute, Resilient Indicator and Score (PARS) methodology - a conceptual framework developed for assessing the climate change vulnerability of coastal livelihoods. The methodology provides

prioritization and ranking of the different impacts as perceived by the fishers. The assessment of fisher's perception on climate change effects across fishing villages' vulnerability, 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 indicated that the long term effects of climate change aren't realized adequately by 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 couldn't correlate environmental changes consequent to climate change to their livelihood. The fishers were more 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 to climate change by involving them in the disaster preparedness, management and mitigation planning and implementation process.

Greener production systems for the future – cage culture 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 valued species, the production of 3-5 t/cage can be attained with an economic return of 6 to 10 lakhs per harvest, spreading over a period of 6-8 months depending on the species. The life of cage frame is above 5 years. Since the MoA/NFDB have recognized this as a government scheme eligible for 40% subsidy, the technology is gaining popularity among coastal fisher folks. Seed inputs are abundantly available along the coast and fisher folks are skilled in garnering them. Feasibility of several species emerging as candidate species for cage culture is due to the on-going breeding programmes and the possible collection from the sea may deem 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. Results of this study indicated the highest observed omega-3 fatty acid composition (16.98%) in the fish meal fed by this feed. Similarly, there are millions of hectares of flow lying saline areas which are not utilized and can be brought under mariculture with suitable incentives from the government and NFDB. CMFRI has established the first Recirculating Aquaculture System (RAS) 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 approach is for production of fertilized eggs and 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 somewhat complicated and risky. Hence, private entrepreneurs may not be enthusiastic in



Fatty acid composition of pompanos fed by experimental feed formulation developed by CMFRI

marine fish seed production. Further, a regulation of fish seed production under public sector also ensures quality seed production.

Aquatic nutraceuticals: green technologies to develop health products

Chemical compounds with oxidation-inhibiting and anti-inflammatory properties are present in tropical bivalves and sessile marine flora such as seaweeds as a protective mechanism against various stress factors in coastal and oceanic ecosystems. Rich diversity of marine organisms the coastline of the Indian subcontinent assumes a great opportunity for the discovery of new bioactive substances. Considering the underutilization of these species, exploring high value compounds and development of any biologically useful products has benefits in carbon sequestration and carbon budgeting in a scenario where climate change may pose a serious threat in future. Development of value-added products from these underutilized species will also promote their farming in coastal habitats, which has not been seriously explored earlier due to the lack of knowledge about their commercial importance. In this connection, the scientists of CMFRI explored various marine natural flora and fauna such as bivalve molluscs and seaweeds for their bioactive properties and were able to successfully develop a number of products for use as nutraceuticals and human health. A patented product Cadalmin™ Green Mussel extract (Cadalmin™ GMe) containing anti-inflammatory principles from *Perna viridis* to combat joint pain, arthritis, inflammatory diseases has been developed by CMFRI as an effective green alternative to the synthetic drugs available in the market. Cadalmin™ GMe is an indigenous product, and is highly cost effective with that of the imported products available in the market. Cadalmin™ GMe has been commercialized with Accelerated Freeze Drying Company Pvt. Ltd., a FDA, ISO 22000 FSSC 22000:2011 certified flag Ship company of Amalgam Group of Companies. Cadalmin™ Green Algal extract (Cadalmin™ GAe) is another addition in the pipeline of the green nutraceuticals developed by CMFRI as a natural remady to chronic joint pain and arthritis. Cadalmin™ GAe contains 100% natural and vegetarian marine bioactive anti-inflammatory ingredients, which have been extracted from a blend of marine macroalgae or seaweeds with an ecofriendly "green" technology. This product has been commercialized with Celestial Biolabs Ltd., a GMP/ WHO certified pharmaceutical Company based at Hyderabad.

Societal initiatives for a greener tomorrow in fisheries

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 2012 was 3.94 million t (CMFRI, 2013). 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 fisher has been 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 and fish products recorded highest increase in price among all food commodities-transforming it from a poor man's food to luxurious food item. The percentage share of fishermen in consumer rupee (PSFCR) ranged from 40% for oil sardine to 80% for seer fish in private marketing channels. Wherever Self-Help Groups (SHG's) 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, other than the commercial landing centres. This has led to polarization of harbour based infrastructure development and isolation of small

landing centres. High level of occupational risks and marginalization exist in fisheries. There is also a lack of positive attitude towards non-fisheries livelihood options. The following aspects of fishery socioeconomics 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 such 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 fisher women through capacity building interventions including 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 fishing vessels and optimization of fleet size
- Mandatory sea safety measures
- Introducing new insurance schemes focusing on fishery sector
- Development of bio-shields, installation of early warning systems, and strengthening of PFZ delivery.
- Integrated coastal zone development including responsible coastal tourism

Green repositories – CMFRI initiatives

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. This is an initiative to cut down the paper usage and digital repositories of publications has come up as a green initiative globally.

Fish Watch

Application of ICT is another approach in the recent past for a greener world. 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 16:00 h on working days.

National Fisheries Data Centre

National Fisheries Data Centre of CMFRI is another digital repository aimed at green management of marine fisheries data. CMFRI's marine fisheries database is recognized by the Ministry of Agriculture as the official marine fisheries data of the country. In order to reduce the carbon footprint involved in collection and compilation, CMFRI is going for online data deposition from all field centers with a user friendly graphic user interface device which is being tested and validated.

The Institute has identified many appropriate strategies to overcome constraints in making marine fisheries 'greener' and achieve our goal

in sustaining the production in a greener path by improving the blue carbon. The fundamental tenet that guides the envisaged vision is "Better Science for greener Fisheries". A networked constituency of informed stakeholders holds the key for future developments in the sector. We urge the researchers in fisheries to commit themselves in developing greener technologies for future generations and wish all success for the endeavours taken by the organizers in rightly organizing the Symposium which is the need of the hour.