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Introduction

The implications of climate change are far reaching and there is a need to develop and implement management plans to boost the resilience of fresh, cold-water, brackish, inland and marine systems, as well as the resilience of infrastructure that allow stakeholders to utilize these systems.

A multifaceted action plan would compose several key elements – targeted scientific, a robust coastal ecosystem, community and industry cooperation and climate sensitive technologies with reduced carbon footprints.

Adaptation on fisheries habitat

Habitat mapping and modeling

In the context of climate change, research on fish habitat is of high significance. Regional or zone wise (SW, NW, NE, SE) mapping and spatial representation of Indian aquatic habitat and its linkage with eco-system services is identified as a prospective adaptation option. Habitat mapping could be extended specifically for commercial as well as vulnerable species for better conservation, management and sustainable utilization of aquatic resources. Development of regional as well as species level models with representation of oceanic and climatic parameter variation could predict quantitative changes of climatic stressors. Habitat mapping coupled with regional models and continuous monitoring of habitat change provides better adaptation and management of fisheries habitat.

Mangrove mapping, conservation and restoration

India accounts for nearly 3 % of world's mangrove vegetation and C sequestration potential of mangroves and their sediments makes more

significant in the context of climate change. Mangrove ecosystem provides a significant habitat for several aquatic species and act as breeding ground and nursery of valuable biota. Mangroves ecosystem mapping, conservation and restoration is identified as an adaptation option to enhance coastal resilience. Ecosystem productivity could be increased by improving the habitat resulting in beneficial implications on coastal fisheries. This could to a certain extent supplement the fishermen income, thereby enabling them to adapt to vulnerability and loss of fishing days. Mangrove planting in shallow extensive and semi-intensive aquaculture ponds could be done to abate stress due to high temperatures. Besides, it supports artisanal aquaculture activities.

Adaptation on fishery stocks

Stock modeling

To enhance the resiliency of stocks and their ability to recover from population collapses stock modeling could be done. Several research institutions are capable of carrying this out.

Vulnerability assessment along Indian coastal zones and conservation

Scientific criteria developed by CMFRI for long term vulnerability assessment of Indian marine fishes could be used to assess the species level adaptability to climate change. Species identified as highly vulnerable could be prioritized for conservation and management strategies. Conservation and fishing protocols based on species stock vulnerability could also be developed so as to enhance the sustainability.

Monitoring, Control and Surveillance (MCS)

India has effective Monitoring, Control and Surveillance (MCS) mechanism in the EEZ for sustainable usage of oceanic resources. Highly vulnerable stocks identified after scientific analysis could also be brought under MCS for better conservation and adaptation for an optimum period.

Adaptation on fish stock availability

Potential fishing zone could be identified for reducing scouting time and increasing fishing profitability. Activities at fishing zones could be monitored for sustainable exploitation of fisheries resources.

Fish catch forecast models could be developed for Indian coast, so as to enable the fishermen folks and stakeholders to cope up with the stock shift.

New technologies and fishing methods developed could be implemented in the context of climate change and stock availability. Fishermen folks, self-help

groups and other stakeholders could be trained and empowered to augment marine fish production.

Regulation of fishing (fleet size, mesh size, spatiotemporal closure) could be ensured for sustainable fisheries stock utilization.

Adaptation on the harvesting sector

Implementation of Minimum Legal Size

Catch is of serious concern in the harvesting sector which could be directly attributed to climate change and stock distribution. However, this increases the fishing pressure on vulnerable populations. Hence to bring about sustainability, minimum legal size could be implemented. Better exploitation and utilisation opportunities exist for small pelagics in all the maritime zones

Green fishing protocols for carbon foot print reduction

Alternative energy usage in fishing operations could be considered. However owing to the direct contribution of fisheries sector directly to food and nutritional security to millions of populations, implementation of shift in operational techniques to reduce the C footprint need to be done only after caution.

Adaptation on coastal aquaculture

Identification of climate resilient species suitable for mariculture

After experiments on impacts of climatic parameters, stress tolerant species (Silver pompano, Cobia, etc) were identified along with development of technologies for its culture. As climate change had affected wild species distribution and catch, focus on mariculture is an adaptive option and accordingly identification of stress tolerant species is significant. Zone wise commercially valuable stress tolerant species could be identified and cultured for better adaptation.

Adaptations to integrated farming technologies

Integrated Multi Trophic Aquaculture with farming fish with seaweed and mussel was demonstrated as a successful adaptation measure. Integrated cultivation doubled the weight of seaweed yield and also enhances the fishermen income through co-farming yields as well.

Paddy-fish integrated farming was successfully implemented as an adaptive measure across several states of the nation. Successful demonstration of integrated farming of paddy (pokkali) with finfishes (mullet and pearlspot) in Kerala resulted in profitability (Rs.83,000 per hector per annum) in otherwise

kept fallow paddy fields. Owing to the success, several government agencies initiated schemes for supporting the integrated paddy-fish farming practices.

Regional wetland restoration and implementing scientific fish farming

Wetland restoration along with incorporation of scientific fish farming at village level was identified as a prospective climate resilient strategy. India had developed a spatial database of wetlands through the National Wetland Inventory and Assessment (NWI) project, which reports extend of wetlands estimate as 15.26 mha and inland wetlands of the nation as 69.22% of the total wetland area, whereas the coastal wetland accounts to 27.13% and remaining 3.64% includes small wetlands that are less than 2.25ha (National Wetland Atlas). In India 5,55,557 small wetlands were detected and mapped as point features (Panigrahy Sushma et. al, 2012) Developing wetlands of size below 2 ha for fish farming could enhance the regional resilience along with village level food and nutritional security and the surplus production could be channelized to global supply chain. Beyond assessing and developing for reduced GHG emissions, emphatic and comprehensive focus need to be given on enhancing the wetland ecosystem functions such as productivity, habitat, biodiversity, recreation, etc (Rojith and Zacharia, 2016).

Seaweed farming along Indian coasts

Seaweed farming is identified as a prospective climate resilient strategy. Large scale seaweed cultivation along Indian coastal waters aimed at carbon sequestration, reducing ocean acidification, coastal pollution abatement, co-farming of mussels, oysters and fishes, marine product development, coastal livelihood supplementation and fish feed formulation could enhance the adaptability level of coastal aquaculture. Regional level potential seaweed cultivation zones could be identified and large scale farming could open new horizons in bioproducts and biorefineries industries across the nation.

Development of climate resilient products

Development of climate resilient products from mariculture residues is another adaptive measure. Biochar with C sequestration ability could be further utilized for aquaculture treatment applications. Biofuel production from micro and macro algae is also a significant climate resilient strategy upon which India is focusing.

Adaptation on fishing communities

Climate change preparedness of vulnerable coastal populations

The major Climate Preparedness activities (CPAs) recommended are as Increase awareness, preparedness and adaptation among fishers on climate change

related threats to the livelihood through suitable scientific interactions and trainings, Strengthen supplementary avocations available across the different fishing villages to negate the risks and uncertainties of climate change, Scientifically develop location specific elevation levels for new settlement areas for coastal erosion adaptation, Train on disaster management and evacuation plans.

Strengthen basic amenities in coastal villages

As extreme climate events negatively impacts on basic needs of coastal population, alternative facilities need to be developed for easy access to food, potable water, sanitation, shelters, etc. Local infrastructure (roads, health supports, etc) could be developed for reducing climate change vulnerability. Since fishermen are forced to move out to deeper areas, protection aids must be made available even for traditional /artisanal fishers. Strengthen seawalls and bioshields (coastal forestry). Regulate unplanned coastal activities which would affect tidal amplitudes in village canals/ riparian areas.

Increase disaster preparedness

India had established early warning system and also has a very good natural disaster management system to deal with extreme climatic events. In 2013 a very severe cyclonic storm 'Phailin' equivalent to category 1 hurricane affected around 12 million people of the nation. The cyclone prompted India's biggest successful evacuation in 23 years with shifting of more than 5,50,000 people from coastline of Odisha and Andhra Pradesh to safer places. Successful disaster management plans of the nation could be implemented at each coastal village to cope with even moderate climate change events. Installations of automatic weather stations and similar facilities along with awareness at village level shall enable better weather forecasting and climate change adaptations.

Development and familiarization of E-commerce technologies for fishermen communities

Though E Commerce solutions for fish products are available, gap still exists to develop multivendor platform for directly engaging various self-help groups of fishermen communities as multiple vendors. We are ambitiously working out on the concept to develop such a system for fishermen community livelihood improvement and empowerment. Such systems could be in line with the national goal of farmer income increment. The system could fetch better income as well as better marketing for the engaged fishermen communities.

National policy and planning

Climate change risks assessment and preparedness planning could be done through cooperation between governmental and non-governmental sectors. Social media such as radio, television etc. could be used to inform fishers about weather forecasts and warning and also effective engineering could be put along the coast so as to reduce damage to properties and life.

Adapting aquaculture to climate change could be made through selective breeding, regulating the environment and through resilient species. Schemes could be undertaken to set up mariculture farms/ parks, setting up of hatcheries, capacity building of fishers & entrepreneurs to take up mariculture, development of markets so as to increase fish production from coastal areas.

The Department of Animal Husbandry, Dairying and Fisheries has called for a revolution in the fishing industry, identifying the following objectives for the period 2015/16-2019/20:

- To tap the total fish potential of the country in both the inland and marine sector, tripling production by 2020
- To transform the fisheries sector into a fully modernized one, focusing especially on new technologies and processes
- Doubling the income of fishers and farmers, and establishing better marketing and postharvest infrastructure
- Ensuring inclusive participation of fishers and fish farmers
- To triple export earnings by 2020, with a focus on benefits flow to sector stakeholders through deployment of institutional mechanisms such as cooperatives, producer companies and other structures
- To enhance nutritional security of the country

Establishment of weather watch groups and decision support systems could be done on regional basis. Scientific models such as Mass-Balance models, SEAPODYM etc. that help study the relation between climate change and fish population need to be put into practice.

The mitigation measure for carbon release as a part of fishing activities lies in the fuel use and efficiency of boats and vessels. Over the last 25 years there has been an overall increase of 64 percent of carbon dioxide per tonne of fish caught. Measures to reduce carbon footprint include setting emission norms and improving the fuel efficiency of engines.

Life cycle assessments from pre-harvest to post consumer wastes will provide a more detailed picture of the specific emission sectors that require focus to shift to more sustainable production modes. Switching from fuel intensive techniques to alternatives would use less fuel thereby reducing the carbon footprint of fishing practices. For example the fuel use can be reduced from 9l to 2.2l to land 1kg of Norway lobster, if trap fisheries are used rather than the typical trawling method.

New development schemes for enhancing the skills and capabilities of the traditional fishermen to undertake deep sea fishing shall be introduced. Scope of the Marine Fishing Regulation Acts (MFRAs) of maritime States/UTs to include registration of boat building yards, standard design specifications for boats, construction material and procedures for continuous monitoring and control of boat construction could be enlarged, so that this will produce fuel efficient engines and boats could be considered.

Suggested methods to reduce Green House Gas emission include eliminating inefficient fleet structure, improving fisheries management, reducing post-harvest losses, increasing waste recycling, shifting to more efficient vessels and gears, safeguarding stocks and increase their resilience to climate change. Programmes to maintain cleanliness and hygiene in fish landing centres, harbours and fish markets, building up of infrastructure such as harbour based fish dressing centres & processing estates on a public- private partnership so as to reduce post-harvest losses, measures to reduce post-harvest losses through better onboard fish handling could be put into action.

Promotion of mass cultivation of sea plants that can sequester large quantities of carbon could be considered. Of these green algae *Ulva lactuca*, brown alga *Sargassum polycystum* and red alga *Gracilaria corticata* are more efficient. *Kappaphycus alvarezii* in particular shows promise as a sequestering vehicle for carbon.

Artificial reefs that are made of sand filled geotextiles would help protection of coast from the effects of climate change. Fishermen are aware of the variables of climate and their relation to fish catch. Indigenous knowledge can be made useful for reducing the impacts of climate change on fisheries sector.

Effective and timely warning of population decline of fish species would reduce the pressure on the declining population of small and large pelagics. This would help a smoother transition to other fisheries or industries. Pressures on small

pelagics could be reduced by control and regulation of the number of fish meal plants and by implementing National Marine Fisheries Data Acquisition Plan for the timely, reliable & comprehensive data sets of marine fisheries sector.

Gaps in knowledge

Further efforts to be taken always exist, and this is no less true in the case of institutional response to the damaging effects of climate change. Several key areas exist in which to improve the response to the pervasive effects of global warming.

Common knowledge databases

Common, shared knowledge databases must be made available to researchers across the country. This will streamline research and study in the field of climate change, as significant time is lost on bureaucratic efforts between research organizations during collaborative effects.

Continuous evaluation and fish stock monitoring and dynamic regulation

Constant monitoring of potential vulnerable species, accompanied by dynamic regulation of the utilization of fish stocks could shift the fishery status of certain fish stocks into sustainable territory.

Historical data records for important fish stocks

Data records for important species could be compiled and made publically available to increase transparency and allow for greater insight into population and exploitation trends being displayed by commonly harvested species.

Inclusion of scientific committees in policy determination

Greater involvement of scientific committees comprised of expert panels during the process of policy determination would allow for quicker policy responses to changes resulting from climate change.

Institutional Capability

The Central Marine Fisheries Research Institute falls under the umbrella of the Indian Council of Agricultural Research. Founded in 1947, originally under the Ministry of Agriculture and Farmers Welfare, it comprises seven research centres and three regional centres spread across the coastal areas of the country and is headquartered in Kochi.

Nine divisions including Mariculture, Marine Biodiversity, Fishery Resource Assessment, Pelagic Fisheries, Demersal Fisheries, Crustacean Fisheries, Fishery Environment Management, Marine Biotechnology and Socio Economic

Evaluation & Technology Transfer, one field centre and Krishi Vigyan Kendra work on an integrated approach for improved and timely application of strategies to offset the impacts of climate change on various focal areas of marine fisheries.

The institution is greatly focused on mitigating the adverse effects of climate change and developing new climate resilient strategies for the marine fisheries sector. CMFRI also regularly conducts programmes to disseminate technologies and strategies developed in-house to key stakeholders. Some of the schemes and technologies successfully shared amongst farmers and fishers include:

- Integration of Scientific fin fish farming with traditional Pokkali paddy cultivation,
- Demonstration of small finfish cages for culturing marine fishes
- Development of Technology of Fattening lobster in sea cages to the marketable size,
- Capture based aquaculture for fishermen to harness the positive aspects of climate change
- Identification of climate resilient food crops among halophytes

Some climate resilient strategies to offset the effects of climate change developed by CMFRI include Integrated Multi-Trophic Aquaculture (IMTA), integrated finfish-paddy farming, low cost cage farming, wetland restoration and scientific fish farming, seaweed farming and marine product development, conversion of mariculture residues into biochar, multivendor E-commerce solution for fishermen community, establishment of early warning and weather forecasting system.

Research Interventions towards Climate Resilience through National Innovations in Climate Resilient Agriculture (NICRA) Project of ICAR-CMFRI

ICAR sponsored national level network project to bring out best climate resilient agriculture practices and strategies in each related sectors and ICAR-CMFRI has been entrusted with marine fisheries sector. The climate change research task was undertaken across the total operating centres (Research and Regional) at Cochin, Calicut, Mangalore, Mumbai, Tuticorin, Veraval, Chennai, Vishakhapatnam and Mandapam.

NICRA project could bring several major outputs and outcomes. The project enabled the formulation of scientific criteria to assess the vulnerability of marine species of the nation, which is first of its kind and pave ways for future research in

this direction. Identification of climate resilient species was also established through the project, which is another significant research area. Facilities procured through the research could facilitate climate research progress across the various centres of CMFRI. Research vessel F.V. Silver pompano completes 100 cruises and contributes a lot to oceanic sample collection. Environmental chamber installed at Mandapam is also first of its kind facility in the nation, which boosts the research a lot.

Several climate resilient products development research could also be accelerated through the project. Biofuel and biochar production from aquatic vegetation such as Seaweeds and Water Hyacinth has been attained, which paves way towards exploration of new horizons of climate resilience in marine fisheries sector. Beneficial effects of biochar in fish and paddy growth could also be established through the project.

Assessment of climatic parameters variation along Indian coast and its impact on marine sector revealed changes in distribution, abundance, phenology and trophodynamics of several marine fishes. Some species were found to have positive influence on maturity and spawning season in relation to climate change (SST and rainfall). A scientific criterion was developed for vulnerability assessment of Indian marine fish stocks to climate change and resilience options has been identified. Several adaptation, mitigation and resilience options for Indian marine sector have been recognized through the project. In order to harness the beneficial effects of climate change, resilient species (Silver pompano) for mariculture were identified by experiments. Pearl spot was also identified as a stress tolerant climate resilient species. "Pearl Plus", a feed for pearl spot fish and *Jaiva pokkali*, a brand of organic rice was developed with support of NICRA project. Carbon sequestration potential of seaweed (*Kappaphycus alvarezii*) was confirmed and its large scale farming has been identified as resilient strategy. Several farmers, scientific persons and other stakeholders have been empowered through training and technology demonstrations (Low cost cages, All weather moorings, IMTA, Integrated fish-paddy farming, etc). Technology demonstration units and related infrastructure were also developed through NICRA. 9 National HRD programs for scientists and stakeholders were conducted towards capacity building activities. Compilation of ITK of Indian marine fishermen to climate change has also been brought out. The Fish Farmers Development Agency (FFDA) under the state government has initiated a scheme - Integrated fish farming in Pokkali fields - in collaboration with NICRA and KVK to popularize the technology among farmers of Kerala.

NABARD also sanctioned Pokkali Farmer Producer Company (FPC) as an outcome of the NICRA technology demonstration.

A multivendor E-commerce website hosted as www.marinefishsales.com and associated android application 'marinefishsales' for use in mobile phones has been developed to enable direct sales between fishermen communities and customers. The multivendor e-commerce platform focuses on income enhancement for coastal fishers and farmers. The innovation incorporated is that, in contrary to typical e-commerce ventures where single firm or company as major profit beneficiary, the developed e-platform envisions multiple fishermen self-help groups (SHGs) as beneficiaries. This may be the first instance that a Govt. institution in fisheries sector facilitates the E-Commerce solution, thereby undertaking the greater role to address grass root level climate change adversities through income improvement and livelihood security improvement. Govt. of Himachal Pradesh express interest to implement the similar at their state and enquired for our technical assistance, which was readily agreed upon.

Technical discussions are in final stage with Space Application Centre (ISRO) to collaboratively develop a Webportal and Mobile for data collection of small (<2.2ha) wetlands of the nation. The realization could be revolutionary towards management and continuous monitoring of national regional wetland ecosystem.

Research Ready for Deployment

Following research outputs are ready for deployment or upscaling through NICRA project, which could enhance climate resilience of Indian Marine Fisheries

- Innovative low cost cages for open sea cage culture along Indian coast
- Identification of temperature tolerance in species: silver pompano and pearl spot
- Integrated Multi-Trophic Aquaculture (IMTA) practice
- Integration of fin fish culture with paddy farming
- Biochar from seaweed and water hyacinth for aquaculture applications
- Prototype development of carbon dioxide flow regulator & recorder
- Scientific criterion for vulnerability assessment of marine fishes to climate change
- Multivendor E-Commerce website and android app towards income improvement for fishermen communities
- Biofuel production from seaweed and water hyacinth

Conclusion

Climatic resilience of the marine sector could be attained and the adaptation and mitigation options explored are feasible for time bound implementation. However, more research support could bring these strategies to village level. Climate smart coastal villages could directly contribute towards food and nutritional security of millions and the research interventions in this direction could bring significant improvements. Technology development and empowerment of fishing communities could bring significant changes in the livelihoods as well as national contributions of fisheries sector. E-commerce solution being developed through the project, provides opportunities for the involvement of SHGs of fishermen communities, which could result in the attainment of national goal of farmer income improvement/ doubling. Integrated farming methods are more economically feasible and policies need to be accordingly framed to undertake aquaculture, agriculture and farm tourism as a comprehensive package rather than depending on single sector.

(Adapted portions from own paper SAARC Country Paper - India)

References

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