Chapter 17

Methodologies for Assessing Socio-Economic Vulnerability due to Climate Change Regime

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Introduction

The total fish production in India constitutes 6.3 per cent of the global fish production. Fisheries sector contributes to 1.1 percent of the Indian GDP and about 5.15 per cent of the Agricultural GDP (AGDP). The total fish landing in India is 10.16 million ton with 3.59 MT from marine and 6.57 MT from inland sector. Besides providing livelihood security to around 14.5 million dependents, it also ensures the nutritional security of the huge population of India, with around 60 per cent fish consumers. The per capita fish consumption is 5-6 kg, with states like Kerala having per capita fish consumption as high as 30 kg. India exports around 10.51 L tones of fish with a value of 33,442 crores. As per the CMFRI report the valuation of marine fish in India at Landing Center and Retail Center is around 52,807 and 80,018 crores respectively in 2017. With high growth rates, the different facets of marine fisheries, coastal aquaculture, inland fisheries, freshwater aquaculture, cold water fisheries has immense potential to contribute to food, health, economy, exports, employment and tourism of the country.

Even with increasing growth rate, marine fisheries sector and fisheries sector in general is facing many challenges overcoming which will determine the sustainability of fisheries sector. . The challenges include continued technology drive, over capitalization - mechanization, dwindling CPUE, juvenile fishing/ discards/illegal fishing, disguised employment, sectoral landings/conflicts, low marketing margin and value addition, lack of fishing rights and management dilemma, lack of institutional credit and climate change. Among these, climate change is a factor having multi-dimensional effects on fish, fisheries and fishermen. It is the critical factor which has the potential to make or break the progressive cycle of sustainability that we are aiming towards. It is important that we develop an integrated climate change adaptation and mitigation strategy involving all the stakeholders before it breaks the entire system. .

Climate change and marine ecosystem

The marine ecosystem is constituted by an intricate set of relationships among environment, resources and resource users (Figure 1). Changing climate affects ecosystem in a variety of ways. For instance, warming may force species to migrate to higher latitudes or higher elevations where temperatures are more conducive to their survival. Similarly, as sea level rises, saltwater intrusion into a freshwater system may force some key species to relocate or die, thus removing predators or prey that are critical in the existing food chain. Climate change not only affects ecosystems and resources directly, it also interacts with the general well-being of resource users or community as a whole.

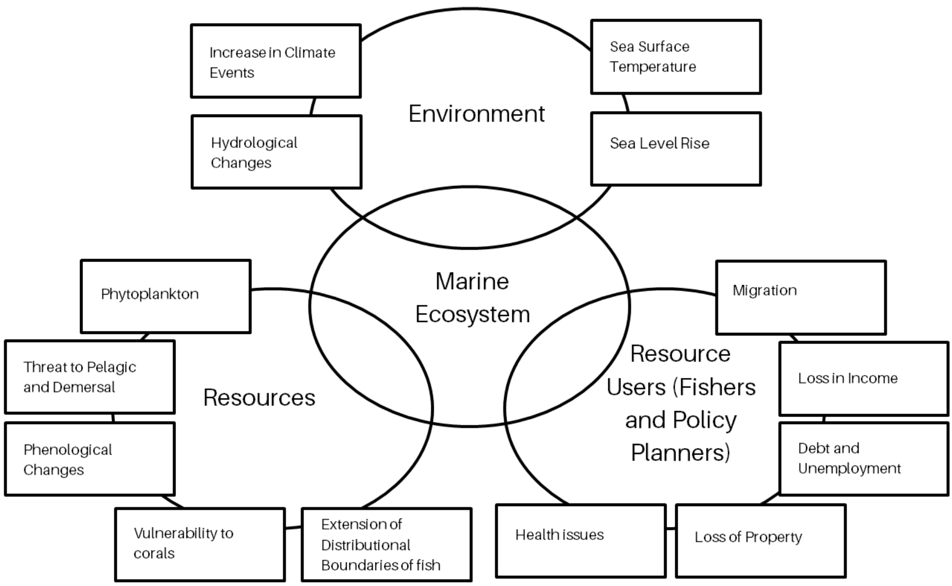


Figure 1. Components of marine ecosystem

I. Impact of climate change on environment

Marine ecosystems are not in a steady state, but are affected by the environment, which varies on many spatial and temporal scales. Changes in temperature are related to alterations in oceanic circulation patterns that are affected by changes in the direction and speed of the winds that drive ocean currents and mix surface waters with deeper nutrient rich waters (Kennedy et al., 2002). These processes in turn affect the distribution and abundance of plankton, which are food for small fish. Understanding the importance and the implication of the climate changes on coastal areas may be one of the major issues for this and next centuries.

Climate changes may, indeed, impact the nearshore marine environment, as coastal areas are very sensitive to the strength and the variability of the meteorological forcings. An increase of a few degrees in atmospheric temperature will not only raise the temperature of the oceans, but also cause major hydrologic changes affecting the physical and chemical properties of water. These will lead to fish, invertebrate, and plant species changes in marine and estuarine communities (McGinn, 2002). Fishes have evolved physiologically to live within a specific range of environmental variation, and existence outside of that range can be stressful or fatal (Barton *et al.,* 2002). These ranges can coincide for fishes that evolved in similar habitats (Attrill, 2002).Estuarine and coastal regions are extremely productive because they receive inputs from several primary production sources and detrital food webs. Yet, these systems present the biota with a harsh environment, forcing organisms to evolve physiological or behavioral adaptations to cope with wide ranging physical and chemical variables. Temperature, along with other variables, causes active movement of mobile species to areas encompassing the preferred range of environmental variables, influencing migration patterns (Rose and Leggett, 1988; Murawski, 1993; Soto, 2002).The predicted increase in major climatic events, such as ENSO (IPCC, 2001), may have drastic effects on fish stocks, especially when combined with other factors, such as overfishing. It has been suggested that reduced survival, reduced growth rate, and diversions of traditional migratory routes can all be caused by ENSO events, exacerbating the effects of intensive harvesting (Miller and Fluharty, 1992). The El Nino phenomenon generates substantial changes in oceanographic and meteorological conditions in the Pacific Ocean, with manifestations impacting the Peruvian coast; this has mainly affected pelagic resources, producing alterations in their biological processes, behaviour, and gradual decrease in their population levels (Valdivia, 1976).

II. Impact of climate change on resources

Climate change will affect individuals, populations and communities through the individuals' physiological and behavioral responses to environmental changes. Extremes in environmental factors, such as elevated water temperature, low dissolved oxygen or salinity, and pH, can have deleterious effects on fishes (Moyle and Cech, 2004). Suboptimal environmental conditions can decrease foraging, growth, and fecundity, alters metamorphosis, and affects endocrine homeostasis and migratory behavior (Portner et al., 2001). These organismal changes directly influence population and community structure by their associated effects on performance, patterns of resource use, and survival. Climate affects the distribution and abundance of species in ecosystems around the world. In the face of rising temperatures, the ocean may experience variations in circulation, water temperature, ice cover, and sea level (McCarthy *et al.*, 2001). Climate-driven fluctuations in regional temperature can further affect growth, maturity, spawning time, egg viability, food availability, mortality, and spatial distribution of marine organisms (Nye *et al.,* 2009). Also affected by climate change are the size and timing of plankton blooms, a major driver of marine ecosystem function with a direct impact on recruitment success and population sizes (Fischlin et al., 2007).

Studies on the impact of climate change on fisheries (fish species, stock distribution etc.) have been carried out mainly by the CMFRI, Kochi. Investigations carried out by the CMFRI show that different Indian marine species will respond to climate change as follows: (i) Changes in species composition of phytoplankton may occur at higher temperature; (ii) Small pelagics may extend their boundaries; (iii) Some species may be found in deeper waters as well; and (iv) Phenological changes may occur.

III. Impact of climate change on resource users

Climate change poses a great threat to resource users, in particular, the fisher communities who are emotionally attached to their living environment as their livelihood is heavily dependent on sea .The impact of climate change in marine resource users includes, displacement of family members, food security issues, Migration of fisherfolk, fall in income level, seasonal employment, change in employment pattern, increased fishing cost, reduction of fishing days etc.

a. **Demography and Social standards:** Displacement of family members increased over the years, the young generation has a tendency to move out of fishing, Food security issues increased rapidly in recent years. Disguised unemployment is rampant in all sectors since earnings from marine fisheries are not proportionate to the increase in fishers. This has instigated labour migration induced by the earning potential in the distant waters coupled with limited resources in their vicinity

b. **Infrastructure sensitivity:** Increased frequency and severity of storms or weather, and sea conditions are, unsuitable to fishing as well as damaging to communities on shore through flooding, erosion, and storm damage. There is proximity to hazard areas the fisher household are highly prone to disaster dwellings and the property loss increased over the years.

c. **Income Effect:** The income levels of fishers decreased substantially over the years. The employment pattern has been mostly seasonal, and alternate avocation options are minimal, there is also economic loss due to loss in number of fishing days. Changed fishing ground caused increased cost of fishing and fish storage. The fuel cost, the cost of fishing gear and boat are increasing significantly over the years.

Vulnerability is a condition wherein the internal ability or lack thereof to cope, recover and adapt to climate stress (Kasperson et al., 2003). Vulnerability has emerged as a central concept for understanding the impacts of climate change and natural hazards, in order to develop adequate risk management strategies. Coastal vulnerability describes the susceptibility of the natural system and of coastal societies (persons, groups or communities) towards coastal hazards. Assessing coastal vulnerability is an important prerequisite to identify the areas of high risk, factors contributing to the risk and the ways to reduce the risk (Brooks, 2005). Vulnerability is multidimensional, dynamic and scale-dependent and site-specific.CMFRI has taken lead in taking up climate change specific research areas for studies and has been instrumental in developing various methodologies to assess the socio-economic vulnerability due to climate change regime.

Methodologies for assessing socio-economic vulnerability due to climate change regime

A. National Innovations on Climate Resilient Agriculture (NICRA)

National Innovations on Climate Resilient Agriculture (NICRA) is the network project initiated by ICAR for studying the vulnerability impact and adaptation options for Indian agriculture to climate change. The objectives of the NICRA project is to enhance the resilience of Indian marine fisheries sector and mariculture to climatic variabilities and climate change through development and application of suitable management measures and technologies to demonstrate season and site specific technologies on mariulture for adapting to current climatic risks;and to enhance the capacity of fisheries scientists and other stakeholders in climate resilient marine fisheries and mariculture research and its application. The methodology developed under NICRA for assessing the socioeconomic vulnerability of coastal village households is given below.

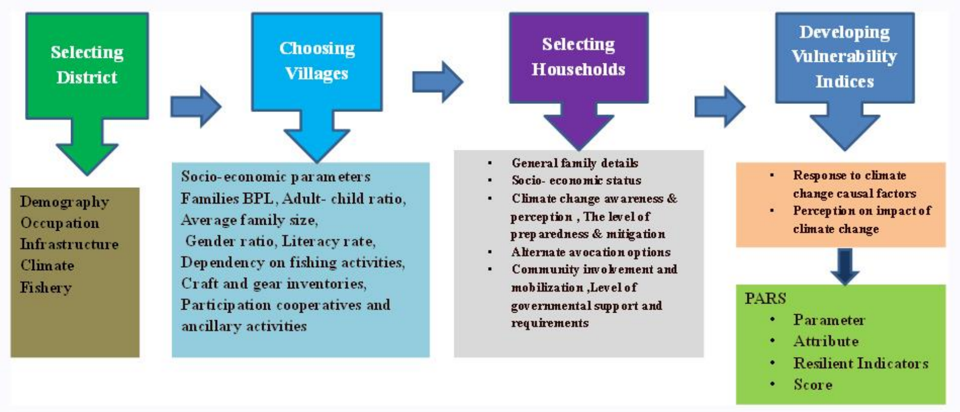


Figure 2. Methodology for assessing the socioeconomic vulnerability of coastal village households

Parameter, Attribute, Resilient indicator and Score (PARS) methodology frame work

Shyam et al., 2014 constructed the vulnerability indices using Parameter, Attribute, Resilient indicator and Score (PARS) methodology, a conceptual framework developed for assessing the climate change vulnerability of coastal livelihoods under the initiative "National Innovations in Climate Resilient Agriculture" (NICRA). Under this initiative, the vulnerability of 318 fisher households in Alappuzha District of Kerala was assessed using PARS methodology (Shyam et al. 2014). The methodology provides prioritisation and ranking of the different impacts as perceived by the fishers on environment, fishery and socio-economic parameters. The vulnerability indices were worked out for the fisher households. The fisher's perception revealed that fishery was most impacted followed by economic and environmental impacts. Social impact was the least as opined by fishers. The study indicates that long term effects of climate change aren't realised/perceived/impacted much among the fisher households. The fishers were more prone to loss in fishing days due to erratic monsoon.

The methodology was employed across the Theme III of IDLAM (Integrated District level Adaptation and Mitigation) and was adopted across the coastal villages of the country. The results suggest a bottom up approach with the proactive participation of the the primary stakeholders awareness by involving them in disaster preparedness, management and mitigation planning as well as implementation process.

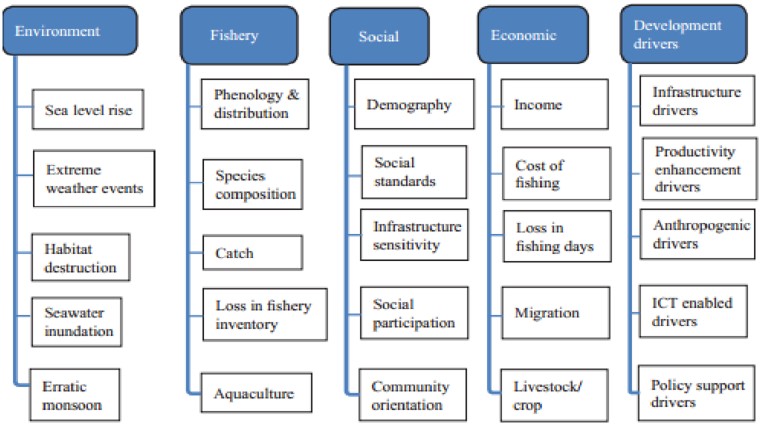


Figure 3. PARS – Climate change perception assessment

B. Australia India Strategic research Fund (AISRF)

AISRF project, based on two workshops, brought together inter-disciplinary researchers from both India and Australia with expertise in physical, biological, social, economic and governance climate change research and developed a strategic research plan for future collaborative research. The workshops identified that the key physical drivers (e.g. temperature, currents) are predicted to affect species abundance and distributions, develop biological, social and economic indices that can be used to monitor impacts on species, industries and rural communities and investigate options for policy and management of marine resources. By developing a strategic and operational plan, the project focused on developing a collaborative research opportunities that can assist Governments, Industries and Communities prepare and adapt to changes in their marine resources. Society, economic and governance differences between India and Australia provided an exciting opportunity to determine generic and specific issues and to adapt concepts and methods across broad biological and socio-economic backgrounds.

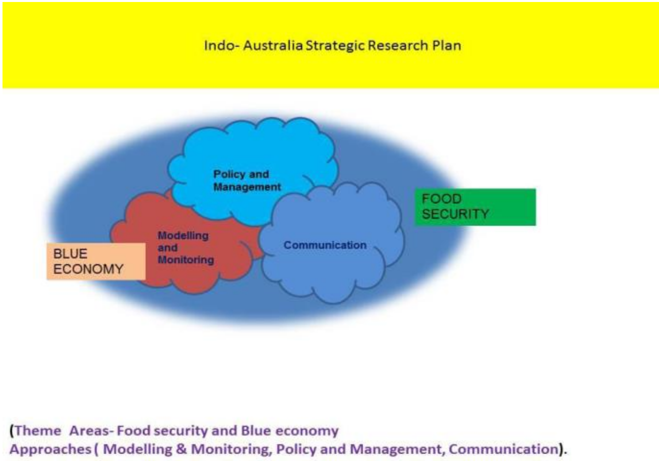


Figure 4. Strategic Research plan

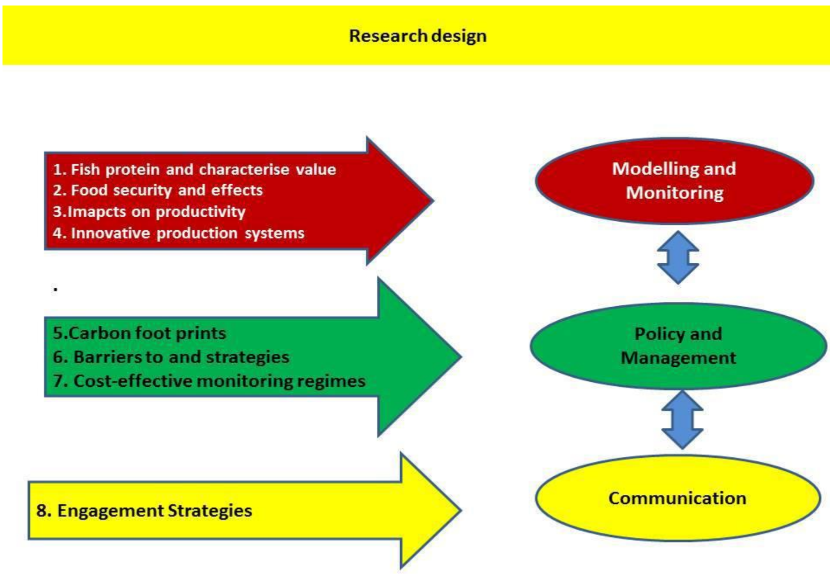


Figure 5. Development of Research / Theme Areas

C. Global understanding and learning for local solutions: Reducing vulnerability of marine-dependent coastal communities (GULLS)

The CMFRI research project on "Global understanding and learning for local solutions: Reducing vulnerability of marine-dependent coastal communities" (GULLS) under the theme on Coastal Vulnerability was sanctioned under an MoU of Belmont Forum and G8 Research Councils International Opportunities

Fund. Focus areas of GULLS project include Southern Africa, Southern Australia, Western Australia, Mozambique channel, Southern India and Brazil. The GULLS project addressed the Belmont Challenge priorities in the area of coastal vulnerability – specifically the challenges that arise in food security and sustaining coastal livelihoods as a result of global warming and increasing human coastal populations. The project is contributing to improving community adaptation efforts by characterizing, assessing and predicting the future of coastal-marine food resources and identification of suitable adaptation options. The rationale for selection of the focus area included early observation of the impacts, strong incentives to initiate adaptive strategies, developing models for early prediction and validation, developing adaptation options and testing for challenges to be met efficiently and effectively.

Identification of climate change hot spots

Climate change Hot spots –can be defined as the ''live *labs'* where the manifestations of the climate change impacts are observed "first". The identification of the climate change hot spots would help policy makers in priority setting and in planning adaptation and conservation measures

The coastal vulnerability assessment in GULLS project underlines, a demarcation between fishery hotspots (based on fish abundance, phenology, distribution, range shifts, recruitment success etc.) and social hotspots (determining vulnerability, displacement, marginalization of traditional community). Consistent with the objectives of GULLS, the activities will be aiming at assessing the current status of the fishery resources and ecosystem services and would attempt at predicting the future impacts of climate change on these resources and services apart from identification of key vulnerable marine species to climate change and assessing the community vulnerability.

The review done in addition to the discussions with the Belmont team resulted in boiling down the hotpsot region to South West and South East Region of India.The South East India encompassing Ramanathapuram and Tuticorin districts of Tamil Nadu and South West India consisting of coastal districts of Kerala including Ernakulum, Alappuzha, Kollam and Trivandrum were selected as hotspots.

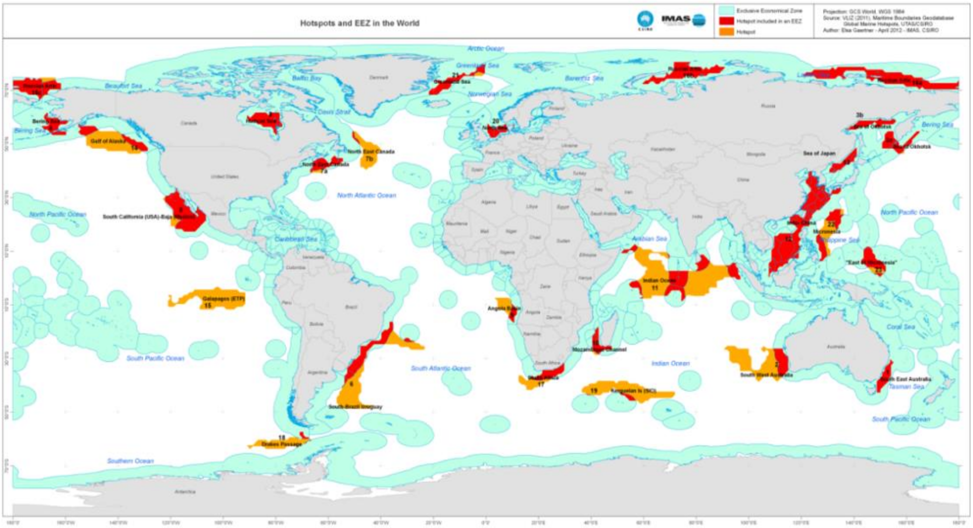
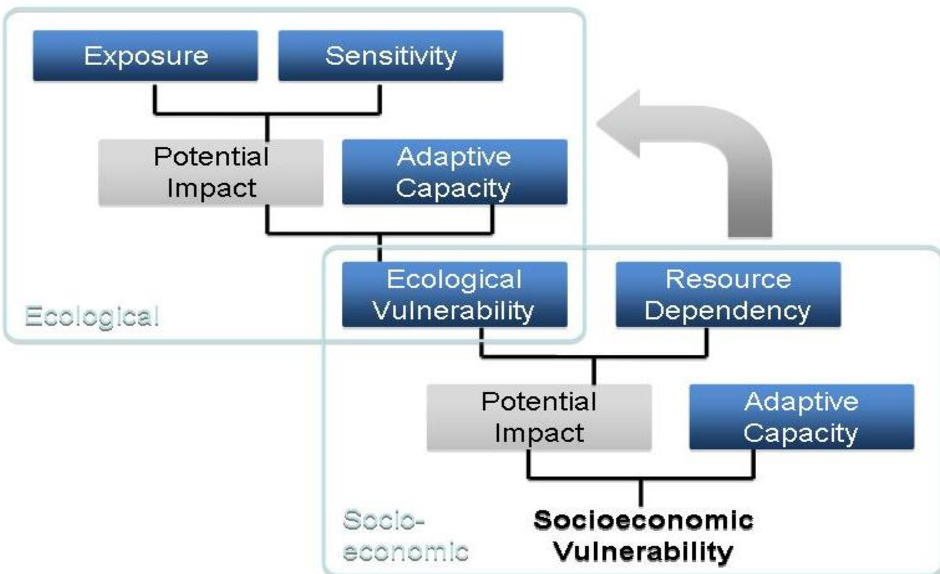


Figure 6. Hotspots - ocean regions experiencing fast warming and those with heightened social tensions as a result of climate change.

GULLS Vulnerability Model *(modified from IPCC)*



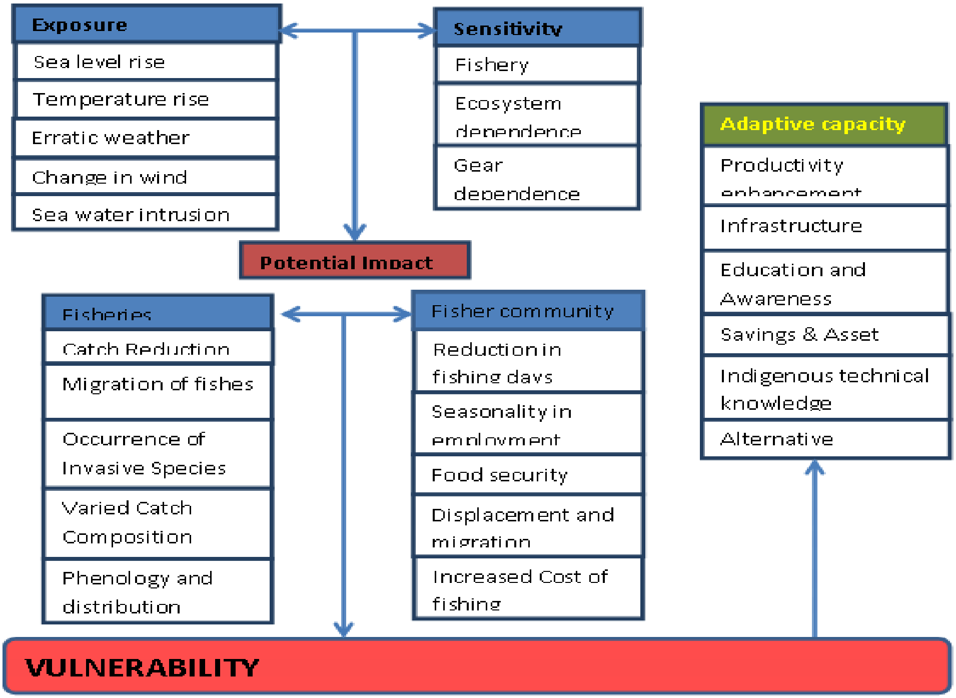


Figure 7. Vulnerability- Key Factors

Vulnerability of coastal regions will be characterized using a linked socio-economic and ecological vulnerability model .The project will be in operation in the different hotspots and will lead to build regional skill-sets that can reduce coastal vulnerability by evaluating and characterizing likely impacts, create predictive systems that will inform decision makers about the expected consequences of coastal changes; deliver alternative options in terms of adaptation and transformation within coastal communities; and to define the long-term implications of selecting a particular option in terms of economic, social and environmental outcomes. Along Kerala coast, two major fishing villages namely Elamkunnapuzha of Ernakulam district and Poonthura of Thiruvananthapuram district in the south west hotspots of India was selected under GULLS project to assess the overall vulnerability of fishery based livelihood due to the impact of climate variation.

A composite vulnerability index approach was used in this study to evaluate relative exposure, sensitivity, and adaptive capacity (Islam et al. 2014). The mean values of the three sub-indices of Exposure (E), Sensitivity (S), and Adaptive

Capacity (AC) were combined to develop a composite vulnerability index by using the following additive (averaging) equation (Islam et al. 2014).

Vulnerability (V) = Exposure (E) + Sensitivity (S) - Adaptive Capacity (AC)
The overall vulnerability values indicate that Poonthura village is slightly more vulnerable than Elamkunnapuzha.The proximity of Poonthura village to the sea can be attributed as the major factor contributing the increase in vulnerability compared to Elamkunnapuzha. In addition higher exposure on account of environmental changes, occurrence of drought and shoreline changes is also attributed to higher vulnerability in Poonthura. However, the sensitivity values are high in Elamkunnapuzha when compared to Poonthura due to high social dependence, economic dependence on other resources as well as historical and cultural dependence on fishing. The adaptive capacity of the selected villages were low when compared to exposure and sensitivity values, indicating the urgent need for developing appropriate adaptive interventions. Therefore, more adaptation options like better policy framework, proper planning measures, and effective disaster management techniques should be implemented to increase the adaptive capacity of the fishermen community to climate change. Improvement of natural capital like steps to curb marine pollution, maintaining prey-predator relationship in the oceans, promoting the culture of species in marine habitats (Cage culture), regulation of fishing rights across the Indian seas, extending the period of trawl ban so as to prevent the recruitment of juveniles entering the fishery maybe looked into as major elements while framing adaptation options.

Table 1. Coastal vulnerability Index of selected hotspots

Region	Sensitivity	Exposure	Adaptive capacity	Overall vulnerability
Poonthura	2.80	2.57	2.52	2.85
Elamkunnapuzha	2.67	2.70	2.57	2.80

CReVAMP
A new framework titled 'CReVAMP' – "*Climate Resilient Village Adaptation and Mitigation Plan"*conceptualised for planning and implementing village level adaption and mitigation plan which is given in the figure no 8. Consistent with the GULLS project objectives, CReVAMP is developed to identify existing climate adaptation and mitigation- probing alternatives and their trade-offs, sensitizing and improving the resilience of community towards climate change

and initiating a multi stakeholders platform for developing a climate knowledge and information systems. The 'CReVAMP' framework presents major elements and approaches through which the desirable outcome is envisaged across different players including individuals, community and the government. This also offers room for defining the 'elements' and 'approaches' in accordance with the village scenario and also for iterative planning of participatory as well as systems-based approaches under which different activities could be implemented with stakeholder engagement for achieving desirable outcome. Considering the sustainability of the adaption and mitigation activities even after the project period, involvement of the climate change agents in the entire process is vital and we have identified a group of people with representation from different age, gender and experience, encompassing articulate children, proactive youth, experienced fishers and committed women as climate change agents in the project.This framework is centered on people and it would help different practitioners to synergize their thoughts and ideas towards planning and implementing different adaptation and mitigation programs thereby helping the community to become climate resilient. In GULLS project we are adopting an integrated approach which would synergize the knowledge system of scientific and indigenous knowledge between the researchers and different stakeholders of the community. It is a balancing act between (i) 'Top Down and Bottom up Approaches', (ii) Prioritized needs of experts and felt need of the communities, (iii) Scientific Knowledge and Traditional wisdom, (IV) Community Solutions and Policy Solutions. This process would be facilitated using multi stakeholder governance model by bringing different stakeholders together to participate in the dialogue, decision making, and knowledge sharing and there by instigate knowledge generation process within the community during the course of the process. The whole process is directed to create village information system within the community, enable green fishing practices and prepare A&M plan for a community which would in turn helps in community empowerment, thus enabling in building resilient community /Climate Change Informed Fisher Community (CCIF). The CCIF is expected to influence the society and government in decision making and actions related to climate change mitigation and would eventually be able to influence the policy making process.

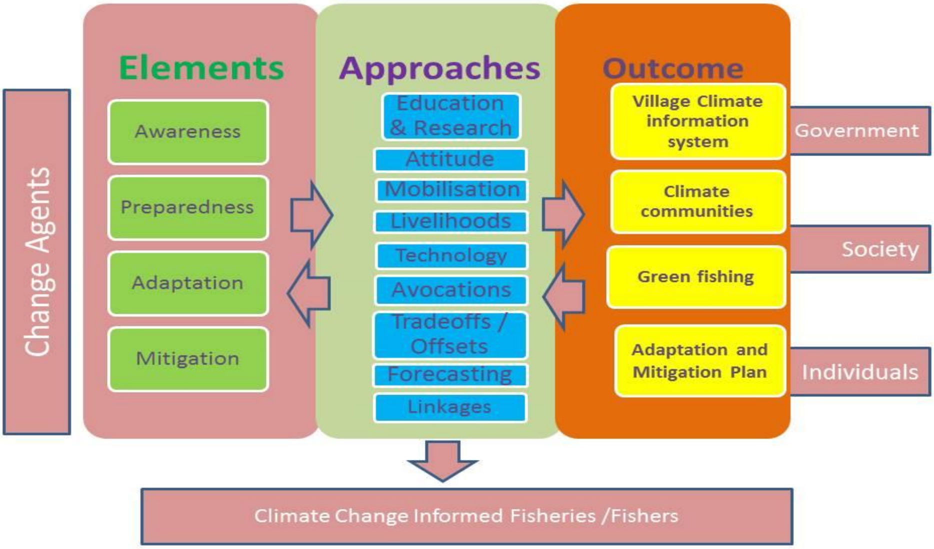


Figure 8. CReVAMP Framework

Climate change - Way Forward

Climate change as a concept is yet to fully sink in to the conscience of the direct stakeholders in the fisheries sector. It is difficult to delineate climate change out of the many factors affecting fishermen livelihood. It is important that as the persons to directly confront the effects of climate change, they are profoundly involved in the process of developing mitigation and adaptation plans. There is a need to create awareness among the coastal communities with regard to the various repercussions of climate change on their livelihood and how they can play a substantial role in mitigating or reducing the risks posed by climate for them and their future generation.

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