

## **Climate Change Impacts on Livelihood Vulnerability Assessment-Adaptation and Mitigation Options in Marine Hot Spots in Kerala, India**

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### **Authors' contributions**

*This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.*

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### **ABSTRACT**

Climate change, a global challenge facing mankind necessitates governments to develop mitigation and adaptation plans. The climate change has multidimensional impacts on environment, fishery, social, economic and development drivers. Climate change hot spots –can be defined as the 'live labs' where the manifestation of the climate change impacts is observed "first". The South west India has been recognised as one among the twenty four hot spot regions identified globally. The present paper assessed the climate change vulnerability of over 800 fisher households in two major fishing villages of Kerala from the south west hotspot regions of India. Exposure (E), Sensitivity (S) and Adaptive Capacity (AC) are the pertinent factors that determine the vulnerability of households which were captured using a structured household questionnaire. One ninety eight indicators were identified in the construction of vulnerability indices of which 37 related to sensitivity, 36 related to exposure and the other 125 indicators dealt with adaptive capacity. The overall vulnerability of the regions was assessed and the analysis revealed that the Poonthura village of Kerala was more vulnerable when compared to Elamkunnappuzha. The coastal population on their vulnerability scores were categorised into low, moderate, high and very high based on score values and geo-spatial analysis was attempted. The results revealed that majority of fisher households in both villages were highly vulnerable to climate change, which is a major cause of concern. The study advocates the need for a bottom up approach with the proactive participation of the fishers in developing location specific adaptation and mitigation plans to ensure the livelihood of the fishers and the sustainable development of the fisheries sector in the climate change regime.

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## 1. INTRODUCTION

Climate change, one of the most debated topics over the last few decades, is no more a myth but a reality. Governments around the world are looking for practical and time-bound plans to cope with the changing environment Shyam et al. [1]. The consequence of climate change is experienced by both inland and coastal regions, but coasts being the transition zone between the lithosphere and hydrosphere are prone to more changes than the other zones. Not only are coastal regions geographically important, but they are vital domains in terms of economy and biology. Sixty percent of the world's metropolises with a population of over 5 million are located within 100 km of the coast, including 12 of the world's 16 cities with populations greater than 10 million IPCC [2]; Shyam et al. [1]. Among the coastal states of India, Kerala stands tall with substantial contribution in the marine landings and value realisation. Even though, Kerala possess third position in terms of marine landings this year (CMFRI 2014) [3], a substantial reduction in the fish landings was reported in the state than the previous year owing to various reasons. In addition to the inherent problems of this sector, the reduction in landings also created food and livelihood security concerns among the fisher folk. There exists an irony that even though Kerala possess the highest literacy rate in the country, the fishers are marginalised and are way behind with comparatively low level of literacy rate and educational attainment which, limits them with minimal alternative livelihood options. Furthermore Shyam et al. [1] reported low level of awareness on climate change among fisher folk of Kerala owing to the fact that climate change issues are entangled with other developmental issues; thereby community could not decipher climate change issues in particular. Though there are many climate change studies done in fisheries sector, it is guiding to the fact that the scientific knowledge generated hasn't trickled down to the grass roots.

However, climate change is not impacting all ocean regions equally with sea surface temperature (SST) warming in some 20 regions occurring at several times the average global rate of warming. Identification of these marine hotspots Hobday and Pecl [4], and the associated biological impacts suggests that coastal communities in these areas may be at

higher risk compared to other regions. These hotspots represent live labs for observing change mainly because impacts are already being observed or will likely be observed early, incentives to develop adaptive strategies will be strong; models developed for prediction can be validated earlier; and adaptation options can be developed, implemented and tested Hobday and Pecl [4].

Ocean warming 'hotspots' or Marine hotspots are regions characterized by above-average temperature increases over recent years, for which there are significant consequences for both living marine resources and the societies that depend on them. As such, they represent early warning systems for understanding the impacts of marine climate change, and test-beds for developing adaptation options for coping with those impacts. These particular hotspots have underpinned a large international partnership that is working towards improving community adaptation by characterizing, assessing and projecting the likely future of coastal-marine food resources through the provision and sharing of knowledge Popova et al. [5]. On the basis of historical observations of Sea Surface Temperature (SST), Hobday & Pecl [4] identified 24 fast-warming marine areas –so-called hotspots and suggested that these could serve as 'natural laboratories' where the mechanistic links between ocean warming and biological responses could be studied in advance of wider scale impacts predicted for later in the 21<sup>st</sup> century. Furthermore, climate adaptation options in marine hotspots could be explored as human dependence on marine resources is very high in many of these areas. During the 21<sup>st</sup> century, changes in ocean physical and biogeochemical parameters are anticipated to greatly impact ocean ecosystems. Coastal-marine food resources will alter as a result of species-specific direct responses to drivers of climate change, such as distribution and abundance of species changing in response to temperature, as already reported from south-east Australia Frusher et al. [6], or ocean acidification in the Arctic (e.g. Mathis et al. [7]). Such impacts to living marine resources will require individuals, communities, industries and governments to understand and adapt to the changing climate Barange et al. [8]; Frusher et al. [6]. However, adaptation options within the context of climate change must build on a solid understanding of the physical, biological and human aspects of the given

systems and recognition that marine systems and human societies are really parts of a unified marine socio-ecological system Perry et al. [9]. However, rising temperatures are not the only climatic factor impacting ocean ecosystems. 'Warming up, turning sour, losing breath' Gruber [10] has become a widely used summary of the major climatic stressors of ocean ecosystems: warming, acidification and deoxygenation, all with implications for marine productivity Doney et al. [11]; Bopp et al. [12]. Changing ocean stratification and circulation may also provide wide-ranging biological effects Doney et al. [10]. Changes in these climatic factors are driven by different mechanisms and different aspects of global ocean dynamics and biogeochemistry Bopp et al. 2013[12], and consequently, patterns of their fastest changes (or hotspots) do not necessarily coincide in space. Although warming of the ocean may not always be the strongest climatic factor affecting marine ecosystems e.g. Maranon et al. [13], the rise of the SST probably remains the most unequivocal signature of the climate change Vivekanandan, [14].

India also has a number of marine hotspots regions. The southern region of India extending from 8°N to 13°N in the Arabian Sea and Bay of Bengal has wide differences in the oceanographic parameters and fisheries. The continental shelf of the Arabian Sea is vast with intense upwelling during the southwest monsoon. The region is rich in productivity and small pelagic species. On the Bay of Bengal side, the continental shelf is very narrow with less productivity. However, both the adjacent regions are subjected to intense fishing activity Rao and Shyam [15]. Studies on the impact of climate change on fisheries (fish species, stock distribution etc) have been carried out by Central Marine Fisheries Research Institute (CMFRI), Kochi Shyam and Manjusha, [16]. 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. This could be explained by taking the case of oil sardine (*Sardinella longiceps*) and Indian Mackerel (*Rastrelliger kanagurta*). These small pelagics, especially the oil sardine, have been known for restricted distribution – between latitude 8°N and 14°N and

longitude 75°E and 77°E (Malabar upwelling zone along the southwest coast of India) where the annual average SST ranges from 27 to 29°C. Until 1985, almost the entire catch was from the Malabar upwelling zone, there was little or no catch from latitudes north of 14°N. During the last two decades, however, catches from latitude 14°N - 20°N are increasing. The higher the SST, the better the oil sardine catch. The surface waters of the Indian seas are warming by 0.04°C per decade. Since the waters in latitudes north of 14°N are warming, the oil sardine and Indian mackerel are moving to northern latitudes. It is seen that catches from the Malabar upwelling zone have not gone down. Inference: The sardines are extending northward, not shifting northward. The Indian mackerel is also found to be extending northward in a similar way.

- (iii) Some species may be found in deeper waters as well. For example, the Indian mackerel *R. kanagurta*, besides exploring northern waters, has been descending deeper as well during the last two decades CMFRI, [17]
- (iv) Phenological changes such as shift in spawning season of thread fin breams, *Nemipterus japonicus* are now evident in Indian seas. The timing of spawning, an annually occurring event, is an important indicator of climate change.

Moreover the earlier reports of Ridgway [18]; Cai et al. [19]; Cai [20] have shown that Southern India is situated in regions that are predicted to warm substantially faster than the global average. As such, the impacts of climate change are expected to be observed and documented in this region first, making it sentinels of climate impacts for other regions in India as well as other regions globally. Parallel with the line of selection of Indian marine hotspots for macro analysis, few definite locations has to be identified based on appropriate indicators for micro analysis, and action. The two districts from the south west hotspot regions namely Thiruvananthapuram and Ernakulam, the highly vulnerable and the moderately vulnerable districts respectively Shyam et al. [1] which are located at the farthest end of the south west hotspot is selected to embrace the maximum diversities for comparison. Moreover Ernakulam, being the commercial capital of Kerala, the options for alternative avocation will be more when

compared to Thiruvananthapuram which also gives adequate scope for comparison.

## 2. REVIEW OF LITERATURE

Although, studies on the assessment of climate change vulnerability on fisheries sector has been done at the global level, very few works focussing on the vulnerability of fisher folk to climate change in the tropical regions have been done at the local level. Some of the studies relevant to the present work are detailed below in review of literature.

The twin problems of unemployment and malnourishment at the rural sphere in India can be simultaneously addressed by proper and planned utilization of available local resources through involvement of local people Datta and Kundu [21]. There are several technical and socio-economic constraints coming in the way of increasing fish production. Several fish production groups / co-operatives are best with untoward socio-economic and socio-cultural features Rahim and Padhy [22] and in many cases there are illiterate / semiliterate, indigent fisherman who lack the knowledge of latest fishery technologies and proper attitude towards fishery development Chakrabarthy et al.[23]. The prospects of fishing enterprise depend in a critical way on the attitude, capability and expectation of the fisher folk associated with the co-operatives Capistrano et al. [24]. Proper management policy involves appropriate choice of inputs that can have a major impact on employment in fishery which inturn influences the economy of the concerned locality Heady [25]. On February 22 2008, the United Nations Environment Programme (UNEP) [26], issued a report titled "In Dead Water: Merging of climate change with pollution, overharvest, and infestations in the world's fishing grounds", warning that three quarters of the world's key fishing grounds are at risk of being seriously impacted by rising temperatures. They reported potential consequences as changes in oceanic circulation patterns, currents that bring nutrients and remove waste from fisheries, rising surface temperatures that are expected to bleach and kill as much as 80% of the world's coral reefs, a major tourist attractions and nurseries for many juvenile fish, and, the possible acidification of the ocean's waters as warmer water absorbs more atmospheric carbon emissions. Increased acidity would impact organisms that utilize calcium for shell-production. According to Intergovernmental Panel on Climate Change [27], climate change

could have dramatic impacts on fish production, which would affect the supply of fishmeal and fish oils and that future aquaculture production could be limited by the supply of fishmeal or fish oils if stocks of species used in the production of fishmeal are negatively affected by climate change and live-fish production. According to FAO [28], the world is likely to see significant changes in fisheries production in the seas and oceans. For communities who heavily rely on fisheries, any decreases in the local availability or quality of fish for food or increases in their livelihoods' instability will pose even more serious problems. From relatively limited and narrow uses two decades ago, the concept of vulnerability has emerged as a key dimension of the development debate, often discussed and analysed along with its counterpart: resilience Miller et al. [29]. Vulnerability is a complex and subjective topic, and its etymology has evolved over time. Many scholars from the natural and social sciences have worked on what vulnerability means in particular disciplinary contexts, resulting in interpretations of vulnerability focused on different components of the social-ecological system under study, different physical and time scales, and different methodologies of investigations. Thus, the disciplinary perspectives from which vulnerability is considered shape the questions asked and the methodologies used to answer these questions, conditioning not only the focus of the analysis and enquiry process, but also the interpretation of the findings and subsequent adaptation actions. For those wishing to implement a Vulnerability Assessment, it is therefore important to understand these disciplinary roots, as this will ultimately influence their understanding of the vulnerability of the system at hand McLaughlin and Dietz [30]. Allison et al. [31] in their work on the vulnerability of national economies to the impacts of climate change on fisheries have compared the vulnerability of 132 national economies to potential climate change impacts on their capture fisheries using an indicator-based approach. They found out that countries in Central and Western Africa (e.g. Malawi, Guinea, Senegal, and Uganda), Peru and Colombia in north-western South America, and four tropical Asian countries (Bangladesh, Cambodia, Pakistan, and Yemen) were identified as most vulnerable. FAO report outlines the interpretation of vulnerability from the risk/hazard, political economy or ecology, and resilience schools of thought. These are three dominant disciplinary traditions, that have a strong influence on how research on vulnerability

is carried out, Adger [32]; Eakin and Luers [33]; Füssel [34]; McLaughlin and Dietz [30]. Popova et al. [5] have examined five hotspots off the coasts of eastern Australia, South Africa, Madagascar, India and Brazil. These particular hotspots have underpinned a large international partnership that is working towards improving community adaptation by characterizing, assessing and projecting the likely future of coastal-marine food resources through the provision and sharing of knowledge. Our simulation finds that the temperature-defined hotspots studied here will continue to experience warming but, with the exception of eastern Australia, may not remain the fastest warming ocean areas over the next century as the strongest warming is projected to occur in the sub polar and polar areas of the Northern Hemisphere. Additionally, we find that recent rapid change in SST is not necessarily an indicator that these areas are also hotspots of the other climatic stressors examined. Hobday et al. in their work on 'Planning adaptation to climate change in fast-warming marine regions with seafood-dependent coastal communities' have described physical, biological, social and governance tools to allow hotspot comparisons, and several methods to evaluate and enhance interactions within a multi-nation research team. Strong partnerships within and between the focal regions are critical to scientific and political support for development of effective approaches to reduce future vulnerability. Comparing these hotspot regions will enhance local adaptation responses and generate outcomes applicable to other regions. Shyam et al. [1] have assessed the socio economic profile and awareness level of the fisher households in the context of climate change in coastal Kerala. The study advocates the need for a bottom up approach in developing location specific plans to ensure the livelihood of the fishers and the sustainable development of the fisheries sector in the climate change regime.

Shyam et al. [16] have determined the scope of developing village level adaptation and mitigation plan for the community through a comprehensive analysis of the community perception on climate change impacts, vulnerability and existing adaptation mitigation strategies using Climate Resilient Village Adaptation and Mitigation Plan (CRvAMP). The study revealed that the actual science and consequences of climate change impacts in a long run are not perceived well. The work suggests that concerted efforts in bringing about resilient community can be achieved through global understanding of the issue and

area specific solutions with the inclusion of the much forgotten social factor- the stakeholders.

Even with the importance of fishing industry in Indian economy, traditional fishing communities, are lagging behind many other communities in terms of socio economic development. The life of the fisher folk is centered on the fishing seasons, the fish they catch and the technology they use. It was estimated that roughly 12.5 lakh people are involved in active fishing while 15 lakh involve in secondary and about 2 lakh in tertiary sectors. The active fishers in the mechanized segment increased from 24 percent in 1980-81 to 35 percent in the recent study and motorized sector from 17 percent to 25 percent. The share of active fishers in the non-mechanized sector decreased from 75 percent to 34 percent. Thus, the objective of the study is to assess the overall vulnerability of fishery based livelihood due to the impact of climate variation using composite livelihood vulnerability index. The study was done by comparing two major fishing villages of Kerala namely Elamkunnappuzha of Ernakulam district and Poonthura of Thiruvananthapuram district. The study also determined the scope of developing village level adaptation and mitigation plan for the community through a comprehensive analysis of the community perception on climate change impacts, vulnerability and existing adaptation mitigation strategies.

### 3. METHODOLOGY

#### 3.1 Spatial Scale and Data Source

The coastal state of Kerala is situated on the southwest coast of the Indian sub-continent, with an area of about 38,863 square kilometres and has a coastline of 590kms, which apparently forms less than 6 per cent of India's total coastline. The fisheries are a source of livelihood for the fishermen in Kerala, with fishing being an imperative part of the economy of the state (Kurien 2001).

Study sites: The present study was conducted in two major fishing villages, viz., Poonthura and Elamkunnappuzha, of Kerala from the south west hotspot regions of India lying between 8°29'N and 76°59' E and 10°00' N and 76°15' E respectively.

The Poonthura village, located in the suburbs of Thiruvananthapuram district, the capital of Kerala, is a coastal village predominantly comprising of fisher-folk settlement. The village

with an area of 0.8 sqkm is a part of the south west coast experiencing tropical climate with a comparatively more active monsoon. The Elamkunnappuzha village is one of the major fishing villages situated in the Vypin taluk of Ernakulam district. It is one of the predominant fishing villages of the commercial capital of Kerala, the Ernakulam.

Coastal fisheries are of immense importance as they provide livelihood opportunities for a large share of the population. The vulnerability assessment using Exposure (E), sensitivity (S) and Adaptive Capacity (AC) as the key factors were collected from 800 fisher households. 198 indicators were used in the construction of vulnerability indices, 37 related to sensitivity, 36 related to exposure and the other 125 indicators deal with adaptive capacity.

Although, Kerala possess the highest quality of life in the country substantiated with human development indicators, the state's fishing communities general development lagged behind other sectors. The level of awareness is minimal which directly indicates the fishers' inability to correlate environmental changes consequent to climate change to their livelihood (Shyam et al. 2013). The fact that the literacy level and educational attainment of fishers is much lower than that of the general population illustrates clearly the plight of fishers when compared to the mainstream population (Panfish Book, 2011).

The villages were ranked in terms of their socio economic performance and the different parameters used in the assessment include number of families below poverty line, adult-child ratio, average family size, gender ratio, literacy rate, dependency on fishing activities, craft and gear inventories, participation in cooperatives and ancillary activities using Patnaik and Narain method (Shyam et al. 2014). Based on the Vulnerability index table, the highest vulnerable villages of Thiruvananthapuram and Ernakulam District, viz., Elamkunnappuzha and Poonthura villages was selected as the units of study.

### **3.1.1 Climate variation in the study region-temperature and rainfall pattern**

Poonthura: Being a part of the south west coast, Poonthura receives active monsoon. The rainfall is received both from the Southwest (June-August) and Northeast (October - December) monsoons with an annual average of 183.5 cm.

Like all other southern coastal areas of Kerala, the soil of Poonthura is loose and sandy. The average temperature in the vicinities was found to be ranging from 16.4°C to 38.0°C, with 85% as the highest range of humidity recorded during the month of June.

Elamkunnappuzha: Receives rainfall from both the Southwest (June-August) and Northeast (October - December) monsoons with an annual average of 309cms. The south-west monsoon provides maximum rain in this region, which brings down the high salinity of the soil and makes it suitable for various seasonal agriculture practices. The weather is of moderate type with a maximum temperature of 30.2°C and a minimum of 20.6°C with very high relative humidity of 85-95%.

### **3.1.2 Occurrence of extreme events-floods and cyclones**

Poonthura: It was reported that Poonthura is exposed to natural calamities like sea intrusion, storms, and shoreline changes. The houses are constructed very near to the sea often resulting in displacement and relocation during heavy monsoon. Even though the tsunami of 2004 did not result in much casualties, it caused huge damage to fishing inventories like boats, nets, houses, and other fishing equipments. The shoreline changes and sea water intrusion were the visible impacts of climate change in this area. According to the respondents the monsoons are a bit ferocious in the area and hence relocations are necessary during monsoons.

Elamkunnappuzha: There were no significant reports on the incidence of storms and droughts in the past five years. The particular observation on climate change related phenomena, which majority of the respondent households could associate with, was the occurrence of the tsunami in 2004. The visible impacts related to climate change that most of the respondent households could observe was a relative increase in sea level and subsequent shoreline changes caused by accretion and erosion. Since majority of the respondent households were located in close proximity to the sea shore such houses were found to be affected by shoreline changes. It was observed that the basements of most of the houses had sunken a few feet deep in to the earth and hence water stagnation was observed in the surrounding areas even inside the compounds of houses. In order to rectify this

problem, many households had resorted to sand filling, or even relocated from the area to safer areas.

### **3.1.3 Fisheries and aquaculture parameters**

Poonthura: Fishing is the major economic activity of the Poonthura village, with 1584 active fishermen in the community along with the allied activities like marketing of fish, curing/processing, peeling, net repairing, etc. Not many mechanized crafts are working in the village. The fishing activity is mainly done with motorized/non motorized canoes, plywood canoes, catamarans, etc.

Elamkunnapuzha: It represents the typical and unique coastal topography of West Coast of India, which is congenial for the techno-interventions of capture and culture fisheries, agri-horticulture and animal husbandry. Fisheries play a predominant role as a major occupation of the vast majority of people in Elamkunnapuzha village. The farmers here adopt diversified aquaculture practices like the monoculture of crabs, *Mugil cephalus* and *Chanos chanos*, and polyculture of different types of finfish Sathiadas et al.

### **3.1.4 Demographic parameters**

Poonthura: According to CMFRI Marine fisheries census (2010), the total fishermen population of Poonthura fishing village is 8871 within a total number of 1290 fishermen families. Out of which, 968 families (75%) come under the BPL category. The average family size is 4.30 with a sex ratio (females per 1000 males) of 982 and with a dependency ratio of 3. Around 20 per cent of the population are having primary education, 3.4 per cent are having higher secondary education, and a mere one per cent was possessing education above higher secondary level. Poonthura village, inhabited by fish workers, has a majority of Latin Catholic Mukkuva (LCM) community, along with a few families from 'Dheevera' community living at the northern part of the village. LCMs are Christians and Dheeveras are Hindus. While the Christian community remains backward in many ways including aspects of sustainable development, in spite of several interventions by NGOs and the Church, the Dheevera community has succeeded to climb up in the development and economic ladder (Nayak 2006). Majority of the population belong to the fisherfolk community

with males outnumbering the females. About 39% of the population possess education above primary level. About 65% of the population are active fishermen and the rest of the population are engaged in other allied activities like marketing of fish, making/repairing net, curing/processing, peeling, Labourer etc CMFRI.

Elamkunnapuzha: Majority of the population belong to the fisher folk community with females outnumbering the males. According to the marine fisheries census 2010, there are about 390 fishermen families out of which 185 families (47%) are under the BPL category. The average family size is 4.46 with a sex ratio (females per 1000 males) of 1006 and with a dependency ratio of 2.99. Out of the marine fisher folk around 21 per cent are registered active marine fisher men, and 50 per cent of them are full time fishers Panfish Book, [35]. About 47% of the population possess education above primary level. CMFRI [36]. The religious orientation revealed that, Elamkunnapuzha village has a majority of Dheevera community (57.6%) followed by Latin Catholics (30.5%) and others (11.8%) Panfish Book, [35].

## **3.2 Selection of the Indicators of Major Components of Vulnerability**

Exposure, sensitivity, and adaptive capacity are the key factors that determine the vulnerability of households and communities to the impacts of climate variability and change (IPCC 2001). Indicators for each of these factors are therefore essential elements of a comprehensive vulnerability assessment. We assume that exposure to climate variations will affect the current sensitivity, either positively or negatively, and that fishers will respond to these changes in a climate sensitive manner if they have sufficient adaptive capacity. There can also be means and measures by which the adaptive capacity could be improved (Fig. 2).

### **3.2.1 Exposure**

Exposure relates to the degree of climate stress upon a particular sector of analysis. It may be represented either as long-term changes in the conditions of climate, or by changes in climate variability, including the magnitude and frequency of extreme events Das et al. [37]. Many climate variables influence fisheries through a range of direct and indirect pathways.

Exposure in the context of this study is the nature and degree to which a fishery-based livelihood system is exposed to significant climatic variations (modified from IPCC 2001). Exposure components selected for the study regions includes attitude and perception to climate change, environmental changes, personal exposure, and occurrence of storms, floods, drought and shoreline.

### 3.2.2 Sensitivity

Sensitivity in this context is the degree to which a fishery-based livelihood system is affected by or responsive to climate stimuli. Sensitivity indicators characterise the first-order effects of stresses IPCC [2]. At the local level, exposure and sensitivity are almost inseparable, and it is challenging to characterise them. The sensitivity parameters included for the present study include livelihood characteristics such as social dependence, economic dependence on fishing, economic dependence on other resources and historical and cultural dependence on fishing. Components reflecting the dependence of the region's economy on fisheries were selected to assess the sensitivity of the sector to potential climate variations Das et al. [37].

### 3.2.3 Adaptive capacity

Adaptive capacity in the context of this study is the ability or capacity of the fishery-based livelihood systems to adjust to climate change (including variability and extremes), to take advantage of opportunities, or to cope with the consequences (modified from IPCC 2001). However, there is little consensus about the characteristics and determinants of adaptive capacity at household, community, and national levels, because the exploration of adaptive capacity has only just begun. The adaptive capacity parameters selected for the present study include flexibility options, social capital, human capital, financial capital, physical capital, natural capital and adaptation options.

### 3.3 Survey Design and Development

In order to ensure clarity of the figure, only a few components for each category are depicted and only some of the sub-components and indicators of each higher level are shown in this figure, generalised survey instrument was developed with questions corresponding directly to each indicator and modified with local community involvement in preliminary field testing.



Fig. 1. Study area – Kerala, India

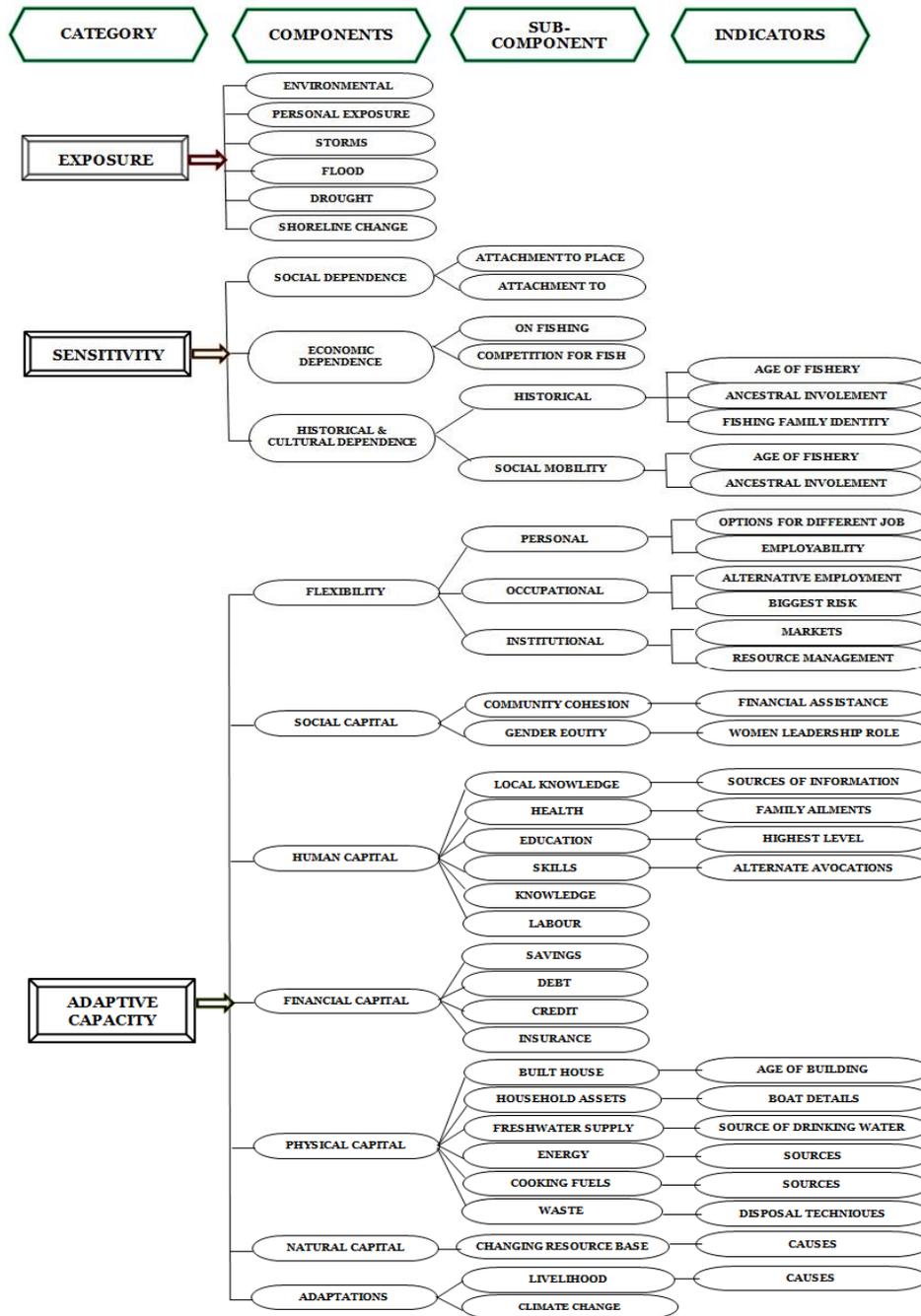


Fig. 2. Category of the integrated framework with exposure, sensitivity and adaptive capacity with different components and its indicators (Make it small case)

### 3.4 Data Collection

Within both communities fishery-dependent households was targeted, which constituted 500 and 300 households from Elamkunnappuzha and Poonthura respectively. The data was collected

during 2014 using a multi-method approach. Sensitivity, adaptive capacity and exposure data were collected using household questionnaires. A stratified random sampling technique was followed to select response households. Participants were mostly head of households or

an adult member. The method of data collection was unique with initially, developing relationships and rapport with the local self-government officials (Panchayath), line departments and women self-help groups within the communities by regular visits and focussed group discussions. Secondly, local self-governments of each district involved in the study educated local people for further training, prior to the implementation of survey. Thirdly, these selected people were trained in topics covering climate change, vulnerability, sensitivity, exposure, adaptive capacity and resource management. They were also specifically trained in conducting household surveys among fishers. Face to face interviews was conducted at household level which almost consumed an hour. Periodic monitoring and evaluation was done followed by a sensitisation workshop for the two study regions. In order to assess vulnerability at household level, the ward details of each study area was collected. The Elamkunnappuzha and Poonthura villages consisted of five and two coastal wards respectively from where data was collected. The data collection aimed at identifying the extent of vulnerability as well as the component structure of vulnerability category measured by items with a Likert-type response scale and to summarize the data contained in numerous items into one or more subscales of vulnerability category that can be used in further models.

### 3.5 Design of a Composite Livelihood Vulnerability Index and Data Analysis

A composite vulnerability index approach was used in this study to evaluate relative exposure, sensitivity, and adaptive capacity (Islam et al. 2014). A composite index approach calculates vulnerability indices using aggregate data for a set of indicators. An indicator represents a characteristic or a parameter of a system Cutter et al. and it is a pragmatic, observable measure of a concept Siniscalco and Auriat. Using the set of indicators described in tables, we quantitatively assessed the vulnerability of fishery based livelihood systems using the combination of individual indicators. Since each indicator was measured on a different scale, they were normalised (rescaled from 0 to 1) by using the following equations

$$x_{ij} = \frac{X_{ij} - \min_i \{X_{ij}\}}{\max_i \{X_{ij}\} - \min_i \{X_{ij}\}} ; \text{ if } x_{ij} \text{ increases with vulnerability}$$

$$y_{ij} = \frac{\max_i \{X_{ij}\} - X_{ij}}{\max_i \{X_{ij}\} - \min_i \{X_{ij}\}} ; \text{ if } y_{ij} \text{ decreases with vulnerability}$$

Where,  $x_{ij}$  and  $y_{ij}$  are the variables representing effects on the vulnerability indices.

The values after normalisation were transformed into a four point Likert scale with assigned score values of, 1 (low), 2 (moderate), 3 (high) and 4 (very high) respectively. 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.

$$\text{Vulnerability (V)} = \text{Exposure (E)} + \text{Sensitivity (S)} - \text{Adaptive Capacity (AC)}$$

Thus, the overall vulnerability index was calculated each for Elamkunnappuzha and Poonthura regions and the computation was attempted to arrive at vulnerability indices at household level. The spatial distribution of households vulnerable under each category for the two study regions were also mapped in a GIS platform using Open domain Quantum GIS (QGIS).

Respondents households were asked to opine responses referring to their knowledge on degree of vulnerability related to various aspects of climate change, livelihood and adaptation and mitigation options etc. Different components were identified under various categories like Exposure, Sensitivity and Adaptive capacity which were found to influence the overall vulnerability of the coastal population of both the study areas (Fig. 2). Data reduction technique using Categorical Principal Component Analysis (CATPCA) was employed to reduce the category components to a number of uncorrelated principal components. The variables employed in the study include nominal and ordinal characterised with non linearity. Therefore linear or standard PCA (Principal Component Analysis) is often not the most appropriate analysis method, although it is commonly used. Consequently, the variables resulting from the questionnaire were ordered categorical (i.e., ordinal) variables. The standard PCA could be appropriately used in the presence of categorical variables only after verified the existence of

linearity in the variables and in the relationships with variables. To avoid the limitations of standard PCA, CATPCA has been introduced and developed during the last 40 years Gifi 1990; Linting et al.

#### 4. RESULTS AND DISCUSSION

The vulnerability of fishery-based livelihoods to the impacts of climate variability and change was assessed using locally relevant indicators of exposure, sensitivity, and adaptive capacity. An understanding of how these components and indicators influence the vulnerability of livelihoods provides an important base for directing future research and climate change coping and adaptation strategies in developing countries, particularly those with fishery systems that are similar to those of India. Fishery-based livelihoods in households of Elamkunnappuzha and Poonthura have high exposure to climate-related shocks and stresses, because the communities are located near the coastline which could be corroborated from the CATPCA results. One of the salient findings of the study is that majority of the respondents were unaware about climate change. The respondents admitted that they are experiencing most of the aftermaths of climate change, however ignorant about the causal factors and likely impacts. According to them the depletion of fish resources, occurrence of extreme events, loss in fishing days, over/targeted fishing are impending factors consequent to climate change.

##### 4.1 Vulnerability

The overall vulnerability values indicate that Poonthura village is slightly more vulnerable than Elamkunnappuzha (Table 1). The proximity of Poonthura village to the sea can be attributed as the major factor contributing to the increased vulnerability. 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 Elamkunnappuzha when compared to Poonthura due to high socio-economic dependence on other resources as well as historical and cultural dependence on fishing which are discussed in the below section (Table 2). 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.

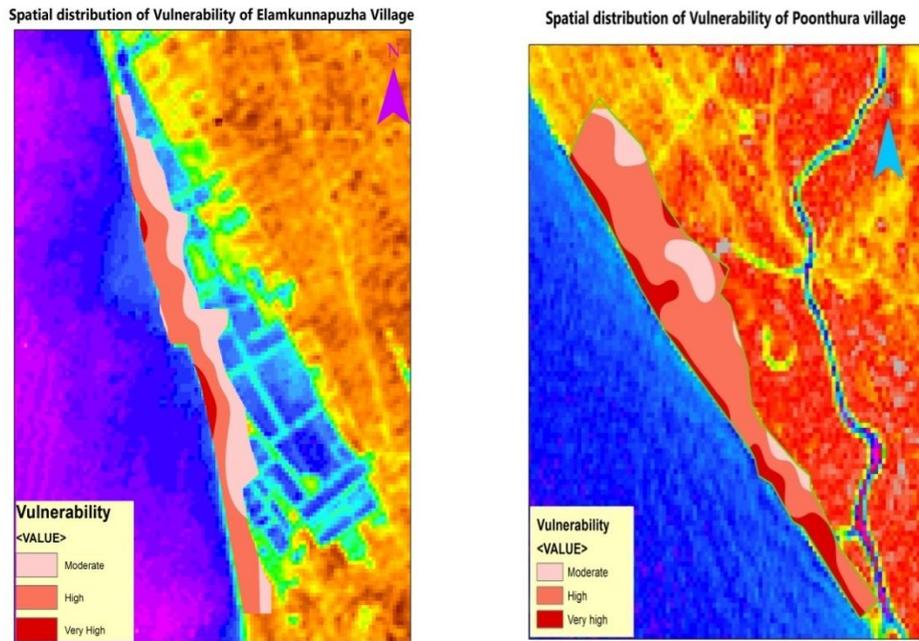
The Fig. 3 represent the overall vulnerability of the household population of Elamkunnappuzha and Poonthura. The colour gradation represents the extent of vulnerability with vulnerability increasing along with increasing colour gradation. In addition, the individual household vulnerability indices were calculated and based on the frequency distribution (Likerts scale) they were classified into low, moderate, high and very high. It was found that about 35% of the population in Elamkunnappuzha are coming under moderate category, 64% of them under high and 2% of them under very high category. On comparison in Poonthura, 18% of the population are represented under moderate category, 63% under high and 18% under very high category. A GIS plot was mapped to see the spatial distribution of households near the coastal area. The plot indicates that the population adjacent to coastal areas are more vulnerable when compared to those residing farther thus, indicating a prominent shift in the spatial distribution. Thus, the coastal side of Poonthura region is inhabited by the very high vulnerable group which is indicated by the dark red portion compared to Elamkunnappuzha where there is less percentage of very high category. However both the regions have almost equal percentages of high vulnerable population contributing to the increasing vulnerability index.

##### 4.2 Exposure

Poonthura had a high exposure value when compared to Elamkunnappuzha (Table 1). This could be substantiated by the CATPCA analysis and also from the figure discussed below. CATPCA was done to delineate the factors contributing to the high values. Under the exposure category, the ordinal variable components/sub components like attitude and perception to climate change, environmental changes, personal exposure, and occurrence of storms, floods and drought and shoreline changes were employed for the analysis. In this analysis, the two dimensional CATPCA on the exposure data ensures the largest eigen value of 2.876 at Elamkunnappuzha, providing that 41.08% of the variance in the transformed variables is explained by the first component. The eigen value of the second component is 1.275, providing that its percentage of variance accounted for is 18.21%. Thus, all of the components account for a substantial percentage of 59.299% and 43.230% of the total variance in the transformed variables at Elamkunnappuzha and Poonthura respectively.

**Table 1. Vulnerability of Elamkunnapuzha and Poonthura**

Locations	Exposure	Sensitivity	Adaptive capacity	Vulnerability
Elamkunnapuzha	2.67	2.70	2.57	2.80
Poonthura	2.80	2.57	2.52	2.85



**Fig. 3. Spatial distribution of Vulnerability along Elamkunnapuzha and Poonthura**

While delineating the different factors which contribute to the loadings under exposure category, it was found that the first principal component is strongly correlated with increasing personal exposure (0.754), and with increasing occurrence of drought (0.603) and floods (0.591) (Table 2). It has also strong correlation with decreasing shoreline changes (-.741) and occurrence of storms (-.719) along Elamkunnapuzha. The lowest value was found for attitude and perception under the first principal component (-.228). On comparison along Poonthura, first principal component is

strongly correlated with increasing environmental change (0.711), occurrence of drought (0.532) and shoreline change (0.540). The lowest value was obtained for personal exposure (0.421) along Poonthura under the first principal component. The second principal component along Elamkunnapuzha is strongly correlated with occurrence of flood (0.622) and drought (0.596) whereas in Poonthura, it is strongly correlated with attitude and perception (0.708), occurrence of floods (0.670) and personal exposure (0.517).

**Table 2. Component loadings under exposure category**

Components	Dimension Elamkunnapuzha		Dimension Poonthura	
	1	2	1	2
Attitude and perception	-.228	-.414	-.084	.708*
Environmental change	-.689*	.391	.711*	-.186
Personal exposure	.754*	-.343	.421	.517*
Storms	-.719*	.125	.495	.107
Floods	.591*	.622*	-.424	.670*
Drought	.603*	.596*	.532*	.189
Shoreline change	-.741*	.275	.540*	.192

*Note: The strongest correlation of a variable to a component appears in asterisks*

The component environmental change indicates an increase or decrease in the following characteristics at sea during the past five years viz. sea level, rain, wind, air temperature, wave height, current strength, rough seas, sea temperature and bottom temperature. Both Elamkunnapuzha and Poonthura have high values pertaining to environmental change which imply that these regions are heavily exposed to the above mentioned environmental parameters. The Indian Ocean tsunami which took place on December 2004 was the only massive recent environmental disaster which occurred along the coasts of Indian Ocean. Eventhough the tsunami did not take any lives; massive destruction was caused to fishing equipments and boats along Kerala coast. In Elamkunnapuzha, an increase in environmental change will lead to an increase in personal exposure, occurrence of storms, drought and shore line change as can be inferred from the results of CATPCA (Table 2). Therefore measures to combat drought, flood and other environmental changes should be taken to bring down the exposure level with regard to climate change along both the locations. Personal exposure include indicators related to whether the house is located in an area that is prone to flooding and also the safety level of the fishermen with respect to their main occupation of fishing in the context of climate exposure. This entails that both the locations are prone to flooding during an event of climate change. The fishers with fishing as their main source of income were highly vulnerable to climate change necessitating the need for alternative avocation in both the study locations. An increase and a decrease in shoreline change will also make the communities vulnerable to high level of exposure. Both the communities are highly exposed to shoreline changes; therefore stringent measures should be adopted to maintain the shoreline level which includes the proper maintenance of bioshields in places where they are present. In those areas where there are no bioshields, steps could be taken to plant the same. Construction of sea walls could also be implemented after studying the aftereffects. The component attitude and perception has low values in both Elamkunnapuzha and Poonthura regions under the first principal component. Attitude and perception includes indicators related to attitude to changes in environment, perceptions of change, and interest in the environment. Attitude to change measures the risk that an environmental change poses to the community, income and livelihood. Perceptions of change

involve the role played by weather conditions while fishing, the extent of difficulty to fish in the areas which the fishers have been fishing and the number of fishing areas which are getting depleted. An interest in the environment relates to ideas to ensure the sustainability of the main species which the fishers catch. In both the study regions the communities' attitude and perception on climate change are low which can be improved by creating awareness on climate change issues and on the need to protect the fishing areas and thereby increasing the biodiversity. To ensure the sustainability of the targeted species, illegal fishing and capture of juveniles should be regulated and adherence to 'Minimum Legal Size' for each species should be complied with. Also, it could be noted that personal exposure which have high value in Elamkunnapuzha is found to be very low in Poonthura which means that the component has less impact on the population of Poonthura.

The figure given below (Fig. 4) depicts the plot of households under exposure category. It could be seen that as discussed above, the population in Poonthura are heavily exposed to climate change compared to those in Elamkunnapuzha. About 52% of the population in Elamkunnapuzha falls under moderate exposure category and about 48% under high exposure category. In Poonthura about 21% of the population is classified under moderate category, 71% under high and about 8% of the population under very high exposure category, which is a matter of great concern. As seen in the earlier figure, the coastal population in the outskirts is highly exposed when compared to others, demarcated by the variation in the colour pattern.

### 4.3 Sensitivity

The sensitivity values were high for Elamkunnapuzha when compared with Poonthura (Table 1). This has been further clarified through CATPCA analysis (Table 3) and also through GIS plots of the two study areas (Fig. 4). To find out the factors contributing to high sensitivity, the following sub components such as socio-economic dependence on fishing, economic dependence on other resources and historical and cultural dependence on fishing were selected for doing CATPCA. In this analysis, the two dimensional CATPCA on the sensitivity data ensures the largest eigen value of 1.287 at Poonthura providing that 32.181% of the variance in the transformed variables is explained by the first component. The eigen value of the second component is 1.078,

providing that its percentage of variance accounted for is 26.956%. Thus, all of the components account for a substantial percentage of 59.137% and 56.374% of the total variance in the transformed variables at Elamkunnapuzha and Poonthura respectively.

While delineating the different factors which contribute to the loadings under exposure category, the first principal component is strongly correlated with increasing social dependence and economic dependence on other resources and with decreasing historical and cultural dependence on fishing along Elamkunnapuzha. Along Poonthura it is strongly correlated with increasing historical and cultural dependence on fishing and with decreasing social dependence (Table 3). Least correlation was obtained for economic dependence on fishing in both Elamkunnapuzha and Poonthura under the first principal component. In Elamkunnapuzha, the second principal component is strongly correlated with social dependence on fishing and economic dependence on fishing, and in Poonthura, the second principal component is strongly correlated with economic dependence on fishing and economic dependence on other resources (Table 3).

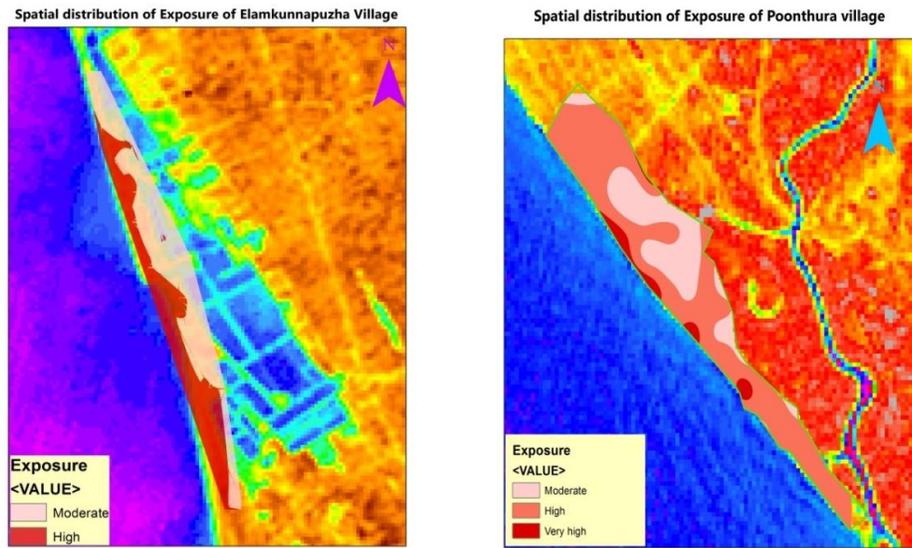
At Elamkunnapuzha, under the sensitivity category, the components social dependence (0.516) (which include the social group like family, fellow workers, scientists, safety authorities, other fishers, marine reserve managers etc. which the fishermen interact with while going fishing), economic dependence on other resources (0.581) and historical and cultural dependence on fishing (-.695) were the factors which have high correlation values under the first dimension. Economic dependence on other resources indicates the most important food source for the households, whether the households possess a garden, and livestock details. Historical and cultural dependence on fishing involve indicators like 'how long have you

been a fisher', 'When did the fishery you are involved with begin in this area', and 'Were previous generations of your family/ancestors fishers' etc. This indicator has high negative values in Elamkunnapuzha and high positive value in Poonthura (0.816). This denotes that the fishermen community have not been engaged in this sector since many past generations in Elamkunnapuzha whereas in Poonthura the fishers have been strongly involved in the fisheries sector since many past generations which make them highly vulnerable to climate change. The high value of sensitivity in Elamkunnapuzha might be due to the high negative magnitude of the indicator, historical and cultural dependence on fishing. In Elamkunnapuzha, the component social dependence and economic dependence on other resources influence each other. In Poonthura also, the component social dependence is found to play a major role. To bring down the high sensitivity in Elamkunnapuzha, the component social dependence and economic dependence on other resources could be reduced and historical and cultural dependence on fishing could be increased. Whereas in Poonthura, the component historical and cultural dependence on fishing should be decreased and social dependence could be increased to lower the sensitivity levels. Social dependence is to be instilled among the fishermen by means of awareness campaigns by deciphering the importance of social values and their role in society, especially among the fishermen community while they go for fishing. The component economic dependence on fishing, which include indicators like 'How many days a week do you and your household consume fresh marine food?', 'Is the fish you eat from your own catch of fish or do you buy fish?', 'Which type of fish do you consume most often?', was found to have a low contribution to the first dimension in both the locations which implies that the indicator has low influence to the overall sensitivity.

**Table 3. Component loadings under sensitivity category**

	Dimension-Elamkunnapuzha		Dimension-Poonthura	
	1	2	1	2
Social dependence	.516*	.644*	-.765*	-.108
Economic dependence on fishing	-.293	.780*	.140	.654*
Economic dependence on other resources	.581*	-.238	-.133	.795*
Historical and cultural dependence on fishing	-.695*	-.050	.816*	-.084

*Note: The strongest correlation of a variable to a component appears in asterisks*



**Fig. 4. Spatial distribution of exposure along Elamkunnapuzha and Poonthura**

The below given figure (Fig. 5) is a representation of households belonging to sensitive category. As given in Table 1, it can be observed from the figure that more number of households in Elamkunnapuzha belongs to high sensitive category when compared to Poonthura. It has been estimated that about 90% of the population belong to high sensitive category in Elamkunnapuzha with about 10% under moderate category. In Poonthura around 70% of the population belong to high sensitive category and 30% belong to moderate category. Almost the entire population in Elamkunnapuzha are highly sensitive; the factors contributing to the same have been discussed in the earlier section.

#### 4.4 Adaptive Capacity

The Adaptive Capacity values were almost similar for both the study locations (Table 1). Under the AC category, the following sub components like flexibility options, social capital, human capital, financial capital, physical capital, natural capital and adaptation options were selected for the analysis. In this analysis, the two dimensional CATPCA on the exposure data ensures the largest eigen value of 1.452 at Elamkunnapuzha providing that 20.747% of the variance in the transformed variables is explained by the first component. The eigen value of the second component is 1.253, providing that its percentage of variance accounted for is 17.902%. Thus, all of the components account for a substantial percentage of 38.649% of the total variance in the

transformed variables at Elamkunnapuzha whereas 39.63% at Poonthura.

While delineating the different factors which contribute to the loadings under exposure category (Table 4), the first principal component is strongly correlated with increasing natural capital (0.517) and adaptation options (0.539) and with decreasing flexibility options (-0.665) along Elamkunnapuzha, whereas along Poonthura, it is strongly correlated with increasing social capital (0.726) and physical capital (0.570). In Elamkunnapuzha, the second principal component is strongly correlated with human capital (0.619) and inversely proportional with social capital (-0.595). In Poonthura, the second principal component is strongly correlated with increasing natural capital (0.757) and with decreasing flexibility options (-0.515) and human capital (-0.518). Low positive values were found for human capital for both Elamkunnapuzha (0.228) and Poonthura (0.104) under the first principal component.

At Elamkunnapuzha, adaptation options which include the various alternatives that the fishermen would likely adopt adverse situations related with extreme climate change, market fluctuations, fish unavailability etc. was found to go hand in hand with natural capital. The natural capital indicators include changing marine resource base, factors that cause decline in fish numbers, factors that could help to increase the number of fish in the sea in the fishermen area and changes that have occurred to their

livelihood as a result of changes to the marine habitat. 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. Steps to improve natural capital like curbing 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 etc, maybe looked into as major elements while framing adaptation options in Elamkunnapuzha.

Flexibility options are grouped under Personal flexibility, Occupational flexibility and Institutional flexibility. Personal flexibility includes indicators to test one's flexibility to change from his present job of fishing to some other job in case of an emergency. Occupational flexibility relates to occupation based indicators like history of employment change, preference of new occupation over previous one, interest in doing a job other than fishing with same amount of profit earning as that of fishing and listing of alternative employment sectors. Institutional flexibility relates to the number of markets where one can buy fish, relationship with middlemen in the community, stability of fish prices, pertinent factor determining the price realisation of fish presence of marine resource management institutions, whether rules or practices have changed in the past in response to environmental changes, the authority to whom the catches have to be reported and list of community organisations. In Elamkunnapuzha as the component 'flexibility options' have a negative impact on adaptive capacity, all efforts should be directed towards improving the flexibility of the community. Providing alternative avocations, imparting counselling to fishers to take up new jobs and to

have a positive outlook towards life during hardships, improving the relationship with middlemen during fish auction, to have a better valuation of fishes and strengthening of marine resource management institutions would definitely help in improving the flexibility. At Poonthura, social capital (family, friends, neighbours, local organisations etc ) which the fishers could assist in times of a financial crisis was found to have a high correlation with physical capital (house details), house hold assets, freshwater supply, source of energy, cooking fuels and waste management options). From this it is convincing that social capital and physical capital are comparatively stronger in Poonthura when compared to other components like human capital and natural capital. Hence measures to improve the health, education, skills, knowledge etc of the fishers (human capital) along with an uplift of the natural capital could be done to augment the adaptive capacity of Poonthura region.

From the figure (Fig. 6) it could be discerned that Adaptive Capacity values are less for the household population in the vicinity of sea at both the locations. The values are found to be increasing for households residing away from the coastal areas as mentioned in the text earlier. Majority of the households (74%) in Elamkunnapuzha belong to high adaptive category and 26 per cent belong to moderate category. In Poonthura, 58 per cent belong to moderate adaptive capacity category and 42% to high adaptive capacity category. In the below figures, a shift in colour gradation from light red to dark red indicates change in adaptive capacity from moderate to high. In both the locations, coastal population residing near the sea were found to be highly vulnerable with moderate adaptive capacity (represented in dark red) compared to those residing inland (light red) with high adaptive capacity.

**Table 4. Component loadings under Adaptive Capacity category**

	Dimension-Elamkunnapuzha		Dimension-Poonthura	
	1	2	1	2
Flexibility options	<b>-.665*</b>	-.193	-.355	<b>-.515*</b>
Social capital	-.180	<b>-.595*</b>	<b>.726*</b>	.003
Human capital	.228	<b>.619*</b>	.104	<b>-.518*</b>
Financial capital	.481	.293	.499	-.367
Physical capital	-.368	.346	<b>.570*</b>	-.072
Natural capital	<b>.517*</b>	-.385	.193	<b>.757*</b>
Adaptation options	<b>.539*</b>	-.354	.490	-.108

*Note: The strongest correlation of a variable to a component appears in bold.*

Note: The strongest correlation of a variable to a component appears in asterisks

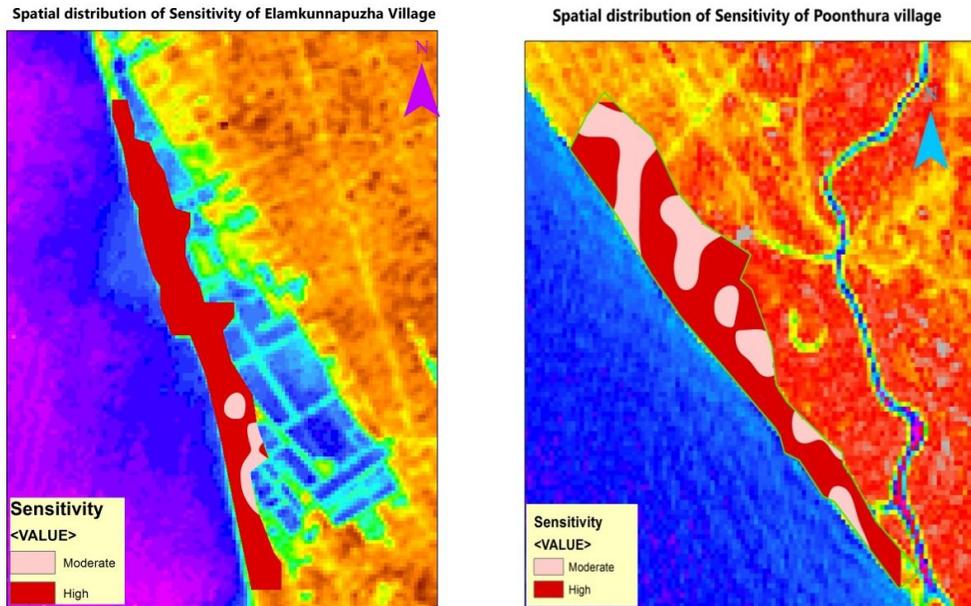


Fig. 5. Spatial distribution of sensitivity along Elamkunnapuzha and Poonthura

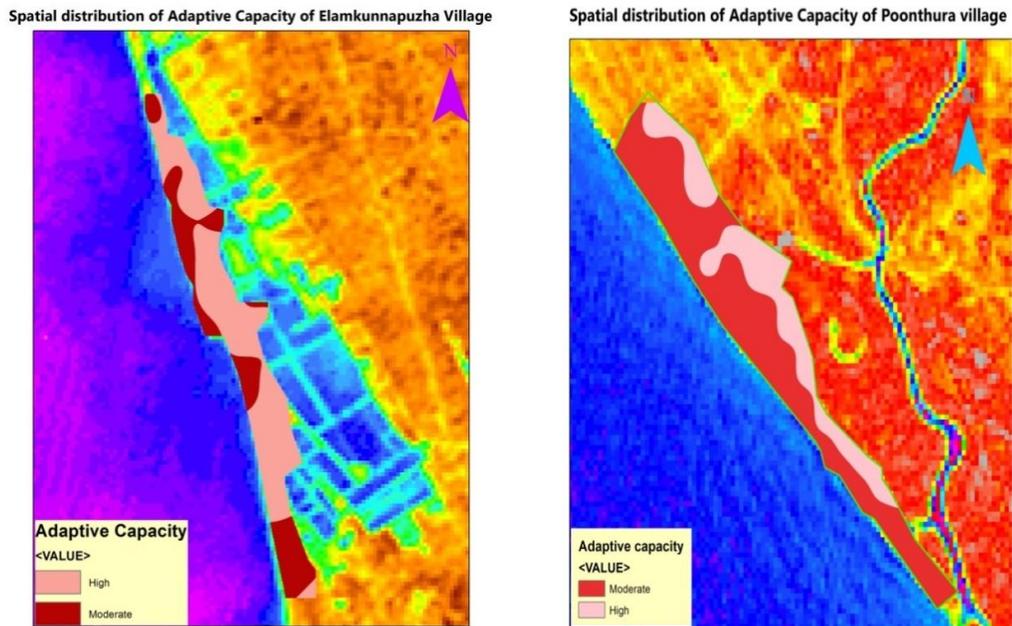


Fig. 6. Spatial distribution of adaptive capacity along Elamkunnapuzha and Poonthura

Exposure, sensitivity, and adaptive capacity influence the vulnerability of fishery-based livelihoods in varied ways. Vulnerability to climate change varies between places, communities, and

social classes Adger; Smit and Wandel. The contextual nature of livelihood vulnerability and considerations of spatial and temporal scale make it challenging to develop robust indicators.

The selection of indicators often involves a trade-off between specificity, transferability, accuracy, and certainty Vincent. In the coming decades, vulnerability of the fishery-based livelihoods may markedly increase because of climate change. In the absence of adaptation, it would result in increased frequency and intensity of storms and floods, greater loss of life at sea and in the coastal zone, damage to fishing materials and household assets, and loss of fishery related income. The future livelihood vulnerability is closely linked with technological, demographic, and socioeconomic trends and how these factors influence the ability of fishery dependent households and communities to adapt.

## 5. CONCLUSION

We analysed vulnerability of fishery-based livelihoods to climate variability and change using a combination of composite indices and qualitative methods. Our findings suggest that different components of vulnerability affect livelihoods in varied ways. The most important climate-related elements of exposure are 'personal exposure' and 'shore line change' in Elamkunnappuzha whereas in Poonthura 'environmental changes' contribute to greater exposure value. In both the locations, the key factors determining sensitivity of an individual household are the indicators related to 'social dependence' and 'historical and cultural dependence on fishing'. The factors influencing adaptive capacity were identified as 'Flexibility options' and 'Adaptation options' in Elamkunnappuzha and 'Social capital' in Poonthura. Thus, it could be inferred from the study that since exposure and sensitivity are governed by the environment, the overall vulnerability could be reduced only by increasing the adaptive capacity of the population. The study has visibly brought out the major areas where thrust is required, to reduce exposure and sensitivity and increase adaptive capacity of the study areas. The results of the study can be utilised by policy makers to frame and enact better policies and management measures. It also provides an important base for directing future research into the vulnerability of fishery based livelihood systems to climate change. Further work is needed in order to move towards an enhanced characterisation of vulnerability and to identify most suitable means for households and communities to cope with and adapt to the impacts of climate change. Thus, findings of this research, it draw that efforts to reduce livelihood vulnerability in coastal fishing communities

should be multidimensional in nature so as to simultaneously tackle exposure, sensitivity, and adaptive capacity. The study advocates the need for a bottom up approach in developing location specific plans to ensure the livelihood of the fishers and the sustainable development of the fisheries sector in the climate change regime with the proactive participation of the fishers.

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## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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