



# Vulnerability Assessment of Coastal Fisher Households in Southern Districts of Tamil Nadu: A Climate Change Perspective

Ranjith L., Johnson B.<sup>1</sup>, Kalidas C.<sup>2</sup>, Linga Prabu D., Sarathapriya D.,  
Karuppasamy K.<sup>3</sup> and Loveson Edward L.

Tuticorin Regional Station, ICAR–Central Marine Fisheries Research Institute, Thoothukudi-628 001, India

<sup>1</sup>Mandapam Regional Centre, ICAR–Central Marine Fisheries Research Institute, Kochi-682 018, India

<sup>2</sup>Karwar Regional Station, ICAR–Central Marine Fisheries Research Institute, Karwar-581 301, Karnataka, India

<sup>3</sup>Fisheries College and Research Institute, Tamil Nadu Dr. J. Jayalalithaa Fisheries University, Thoothukudi-628 008, India  
E-mail: [ranjith\\_bfsc@yahoo.co.in](mailto:ranjith_bfsc@yahoo.co.in)

**Abstract:** Climate change has had a significant impact on both agricultural and aquatic ecosystems. However, research on the vulnerability of the fishing sector is less extensive than that on the agricultural systems. It is imperative to investigate the various climatic stresses that affect the resilience of these ecosystems, which are crucial to the livelihoods of billions of people. The study evaluated the vulnerability index (VI) of three coastal districts in southern Tamil Nadu using the Parameter, Attribute, Resilient indicator, and score method (PARS). Tirunelveli exhibited the highest vulnerability, followed by Tirunelveli and Kanyakumari. The VI ranges for different villages within these coastal districts were as follows: Tirunelveli (0.05 to 0.27), Kanyakumari (0.04 to 0.30) and Thoothukudi (0.03 to 0.31). Thoothukudi Fishing Harbour (0.31) demonstrated the highest vulnerability index, followed by Colachel (0.30) and Uvari (0.27). Additionally, an assessment of 150 fishing households in the Thoothukudi area utilising the rank-based quotient (RBQ) revealed that climate change differentially impacts environmental, fishery, and socioeconomic development factors. The results of the questionnaire survey indicated that climate change predominantly affects the environment, with subsequent effects on fisheries. This study provides foundational information for the vulnerability assessment of the southern districts of Tamil Nadu.

**Keywords:** Climate change, Mitigation measures, PARS methodology, Southern Tamil Nadu, Vulnerability

Climate change is a significant global phenomenon, contributing to increased agricultural losses due to droughts and rising sea levels resulting from excessive rainfall (Nelson et al., 2009). More than half a billion individuals rely on fishery ecosystems for their livelihoods, highlighting the critical importance of ecosystem vulnerability (Allison et al., 2009, FAO 2010, Islam et al., 2014). The effects of climate change, including storms, floods, droughts, sea level rise, sea surface temperature, and precipitation, pose threats to populations that depend on fishing for their livelihoods (Sarch and Allison 2000, Perry et al., 2010). Numerous researchers have investigated the impacts of climate change on Indian fisheries (Vivekanandan et al., 2009, Salagrama 2012). However, there is a paucity of baseline vulnerability assessments concerning the effects of climate change on small-scale tropical fishermen, focusing on the risks faced by inland fisheries (Das et al., 2016) and the susceptibility of coastal fishermen (Patnaik and Narayanan 2009).

India ranks sixth among Asian and tropical countries in terms of coastline length (Central Intelligence Agency 2018), and is recognised as one of the 27 countries most vulnerable to sea level rise, coastal erosion, and flooding. Approximately 35% of the Indian population resides along the 7,516-km coastline (Prasad and Rao 2014). The warming of oceans and melting of glaciers significantly contribute to the Indian

Ocean's role in India's susceptibility to sea level rise. Vulnerability to climate change is a complex process with coastal districts generally exhibiting heightened vulnerability. Therefore, it is essential to assess vulnerability levels by developing a vulnerability index that is specific to each coastal village. Previously, the coastal vulnerability index (CVI) for the coastal zone of Udupi, Karnataka, was calculated using various shoreline change criteria, including the rate of sea-level change, coastal slope, tidal range, and coastal geomorphology (Dwarakish et al., 2009). It was subsequently utilised as an additional parameter to calculate the CVI for Odisha (Kumar et al., 2010). Several studies have evaluated the vulnerability of coastal fishermen's households on the east and west coasts of India (Muktha et al., 2016, Johnson et al., 2016, Geetha et al., 2017, Koya et al., 2017). The east coast of India is more susceptible than the west coast to extreme events, such as cyclones and depressions (Patwardhan et al., 2003).

Tamil Nadu is a leading state in marine fish production, characterised by a coastline extending 1076 km, encompassing 13 coastal districts, and supporting a population of 7,95,708 fishermen across 575 fishing villages (CMFRI-DoF 2020). Numerous studies on sea-level rise vulnerability along the east and west coasts have utilised physical attributes to compute coastal vulnerability indices.

Research on anthropogenic and tsunami impacts on the east coast of India has examined coastal displacement (Murali et al., 2009), run-up, and inundation boundaries (Jayakumar et al., 2005). The most severely affected region is Nagapattinam, which is located in Tamil Nadu's southern state on the east coast (Ramanamurthy et al., 2005). The Thoothukudi, Kanyakumari, and Tirunelveli districts of southern Tamil Nadu are susceptible to both natural and anthropogenic disasters. The majority of inhabitants in these areas are fishermen residing in huts and face socioeconomic challenges. The southern districts of Tamil Nadu were selected as model maritime states for this study because of their significant contribution to fishery-related industries. This study was conducted to identify the susceptibility indices of coastal villages in three districts in response to climate change, facilitate the planning and implementation of disaster management and mitigation strategies.

**MATERIAL AND METHODS**

**Selection of study location:** The study was conducted in the southern districts of Tamil Nadu, namely Thoothukudi, Kanyakumari, and Tirunelveli, spanning from Vembar in the northern part of Thoothukudi (9°04'42.6"N 78°22'01.6"E) to Neerodi in the northern part of Kanyakumari (8°17'22.4"N 77°06'05.8"E). Total coastline 283.9 km, comprising 223.9 km of west coast (from Vembar the southern tip of Kanyakumari), and 60 km along the west coast i.e., from the southern tip of Kanyakumari to Neerodi (Fig. 1).

**Vulnerability index:** The methodology employed was adapted from Patnaik and Narayanan (2009). Parameters, including demography, occupation, infrastructure, climate components, and fishery components, were assessed for various coastal districts, forming the basis for deriving vulnerability indices for these coastal districts. The framework for constructing the vulnerability index is illustrated in Figure 2. The average index for all four impacts and the vulnerability index were calculated using Equations 1 and 2, respectively (Patnaik and Narayanan, 2009).

$$\text{Average Index}_i = (\text{Indicator 1} + \text{Indicator 2} + \dots + \text{Indicator J}) / J \dots\dots\dots 1$$

$$\text{Vulnerability Index} = \left[ \sum_{i=1}^n (\text{Average Index}_i)^\alpha \right]^{1/\alpha} / n \dots\dots 2$$

J denotes the number of indicators in each source of vulnerability and n denotes the number of sources of vulnerability.

In selecting coastal villages within the designated coastal district, several factors were considered, including socioeconomic parameters, the number of families living below the poverty line, adult-child ratio, average family size, gender ratio, literacy rate, dependence on fishing activities,

inventories of crafts and gear, participation in cooperatives, and ancillary activities. The sampling strategy prioritises the distribution of coastal households to establish vulnerability indicators. Data were collected from various villages using a predefined schedule encompassing multiple aspects such as family characteristics, education, asset details, savings, farming practices, and livestock, primarily focusing on perceptions of climate change awareness and its underlying causes.

**Selection of coastal districts:** Based on Patnaik and Narayanan's (2009) model, the coastal district vulnerability index was calculated, and the districts were chosen based on an evaluation of the coastal district vulnerability index calculated for each coastal district of Tamil Nadu. The PARS (Parameter, Attribute, Resilient Indicator, and Score) approach was employed to produce vulnerability indicators, and a conceptual framework was created to evaluate the susceptibility of coastal livelihoods to climate change (Koya et al., 2017). The fishermen were asked to rate their vulnerability on a scale ranging from 1 to 5, representing how serious the vulnerability was - five was very high, four was high, three was medium, two was low, and one was negligible/marginal. Thus, every parameter would result in a distinct attribute, which would result in a different statement or resilient indicator that would be determined by a different score. This approach is highly helpful in determining which parameter, or attribute of the parameter, is the area most vulnerable to climate change. The IDLAM study was conducted over a 12-month period in the Threspuram fishing village. Villages were selected based on a comprehensive index developed using the aforementioned parameters. A total of 150 fishing households distributed across the three fishing villages were selected using proportionate random sampling, and the PARS methodology was employed to assess the vulnerability of coastal livelihoods.

**Validation:** The scores were analyzed using the rank-based quotient technique, and the ranks were assigned such that the attribute that was most impacted was ranked highest. The values of each statement were measured, and 125 statements in the schedule that dealt with climate change were analyzed. The following Rank Based Quotient (RBQ) formula (Sabarathnam 1988) was used to assess the PARS approach.

$$\text{Rank Based Quotient} = \sum_{i=1}^n (F_i)(n+1-i)X \frac{100}{Nn}$$

where,

Fi = Frequency of respondents for the ith rank; N = Total number of respondents; n = Total number of ranks/factors.

This methodology is useful for determining which parameter or attribute of the parameter is the most vulnerable

factor of the area in terms of climate change via first-hand analysis. Thoothukudi fishermen's perspectives on climate change vulnerability were generated through various participatory programs aimed at raising awareness and encouraging preparation and mitigation measures.

**Mapping:** The vulnerability indices of different coastal villages integrate various elements into a spatial representation at the village level, enabling the quantification of vulnerability and its contributing factors while also identifying indicators that require further investigation and suitable adaptive measures.

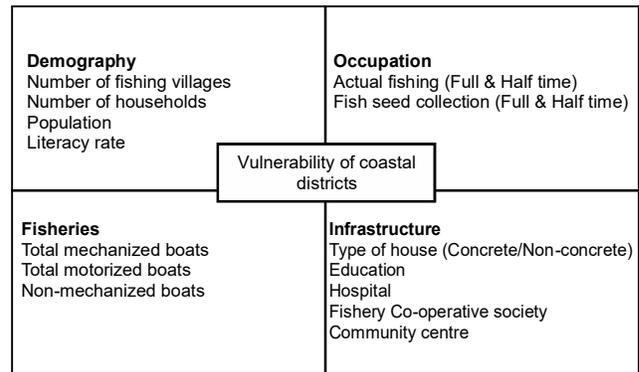
**RESULTS AND DISCUSSION**

The VI results of the three coastal districts, based on the PARS methodology, revealed that Tirunelveli had the highest average vulnerability (0.15) followed by Kanyakumari (0.13) and Tuticorin had the least average VI values with 5 taluks ranging from 0.03 to 0.31. However, Thoothukudi Fishing Harbour (0.31) is known for its highest value among all villages in 3 districts. The coastal villages and taluks selected for the vulnerability index assessment are shown (Fig. 3) and the detailed VI values for each coastal community and extremely susceptible villages for all three 3 districts are explained in the following sections.

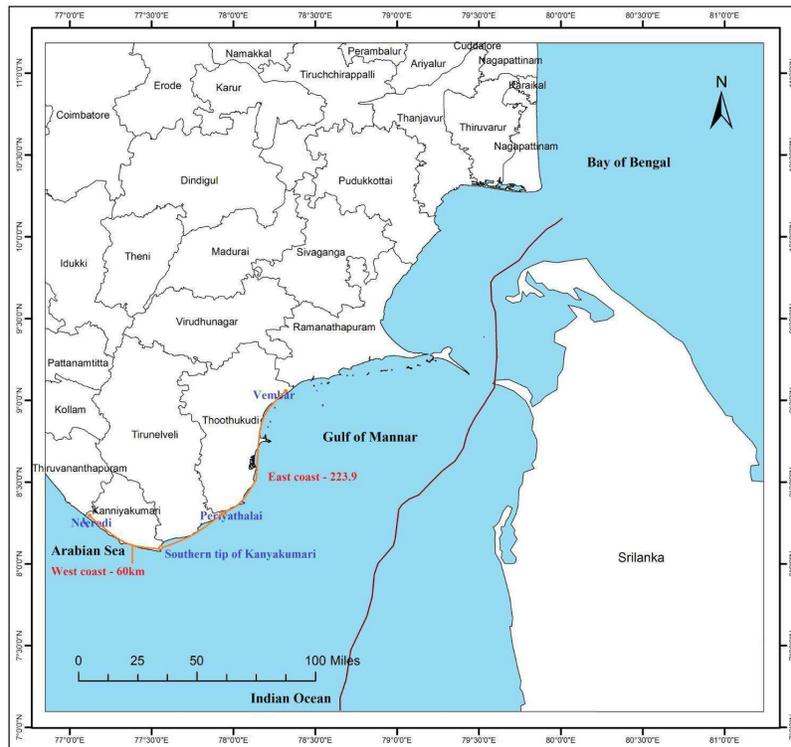
**Vulnerability index for the Thoothukudi district:** The average vulnerability Index of the six Taluks of Thoothukudi

was estimated to be approximately 0.11 and Sathankulam Taluk had the highest VI (0.14). Among the 32 coastal fishing villages in the district, Thoothukudi Fishing Harbor (0.31) had the highest Vulnerability Index, followed by Therespuram (0.22) (Table 1).

**Vulnerability indices for the Tirunelveli districts:** The vulnerability index (VI) of the fishing villages in the Tirunelveli district ranged from 0.05 - 0.27. The VI was highest in Uvari (0.27), followed by Idinthakarai, Thomaiyar Puram and Radhapuram Taluk (Table 2).



**Fig. 2.** Framework for constructing the vulnerability index (VI), as modified and adapted from Koya et al. (2017)

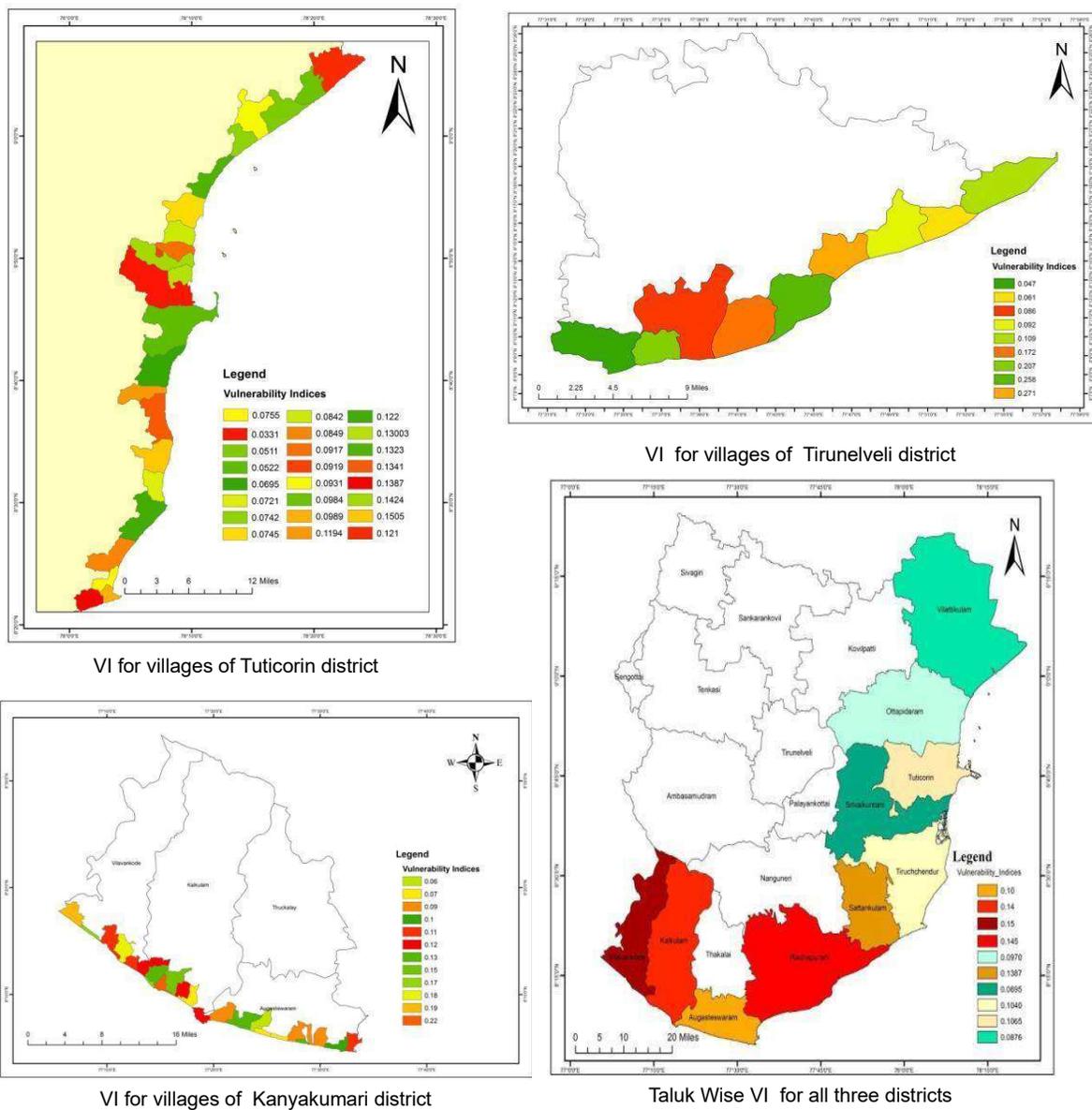


**Fig. 1.** Study location from Vembar to Neerodi along 3 southern districts of Tamil Nadu

**Vulnerability indices for the Kanyakumari districts:** The Kanyakumari district comprises three taluks, with an average VI of 0.13, with Vilavancode as the first place, with an average of 0.15. These taluks extend from the southeast coast of Arockiapuram to Neerodi in Southwest India. The vulnerability index (VI) of the 47 fishing villages in the Kanyakumari district ranged from 0.05 to 0.30 (Table 3). The VI was highest in Colachel (0.30), followed by Eraviputhenthurai (0.25), and lowest in Puthugramam (0.05). **Fishers' perception of the effect of Climate change:** Using the PARS methodology, five parameters with different attributes were selected to assess the impact of climate

change on the selected study areas. The data perceived from Threpuram fishing village revealed that climate change is most negatively impacted by the environment, with fishery as the second, and social and economic issues coming under the third followed by fishery and economic parameters. Development drivers are known to have the least impact parameter, according to fishermen's perceptions (Fig. 4).

**Effects of casual factors on Climate change:** The leading factors were temperature (75.95), wind (70.41), industrialization (69.59), and orbital variations (69.73) (Fig. 5). The biggest contributor to climate change is global warming, because rising temperatures cause sea levels and



**Fig. 3.** Maps of vulnerability indices (VIs) for the fishing villages of the Thoothukudi, Tirunelveli, and Kanyakumari districts and the combined Taluk Wise VI map for all three districts

**Table 1.** Vulnerability indices for the fishing villages (Taluk Wise) in the Thoothukudi district

Taluk - I Thoothukudi	VI	Taluk -II Tiruchendur	VI	Taluk -VI Ottapidaram	VI
Alangarathatu	0.07	Alanthalai	0.08	Vellapatti	0.08
Ananda Nagar	0.03	Amalinagar	0.10	Pattinamaruthur	0.07
Inico Nagar	0.07	Jeevanagar	0.08	Tharuvaikulam	0.13
Loorthammalpuram	0.08	Komputhurai	0.12	Average	0.10
Meenavar Colony	0.09	Kulasekara Patnam	0.07	Taluk - V Vilathikulam	
Mettupatti	0.09	Manapad	0.13	Keezhavaipar	0.07
Rajapalayam	0.03	Punnakayal	0.15	Periyasampuram	0.09
Siluvaipatti	0.05	Singithurai	0.12	Sippikulam	0.05
Thalamuthu Nagar	0.09	Tsunami Nagar (Anna Nagar)	0.13	Vembar (South)	0.10
Therespuram	0.22	Veerapandian pattinam	0.06	Vembar (North)	0.12
Thoothukudi Fishing Harbor	0.31	Average	0.10	Average	0.09
VOC Statue	0.13	Taluk - III Sathankulam		Taluk - VI Srivaikundam	
Average	0.11	Periyathalai	0.14	Pazhayakayal	0.07
Total average of 6 Taluks					0.11

**Table 2.** Vulnerability indices for fishing villages (Taluk wise) in the Tirunelveli district

Village	VI	Village	VI	Village	VI
Taluk: Radhapuram					
Idinthakarai	0.26	Kooduthalai	0.11	Koottapannai	0.06
Kuttapuli	0.21	Kuthenkuli	0.17	Periyathalai	0.09
Perumanal	0.09	Thomaiyarpuram	0.05	Uvari	0.27
Average					0.15

**Table 3.** Vulnerability indices for fishing villages (Taluk wise) in the Kanyakumari district

Taluk-I Agasteeswaram	VI	Taluk-II Kalkulam	VI	Taluk-III Vilavancode	VI
Annai Nagar	0.11	Chinnalai	0.07	Enayam	0.16
Arockiapuram	0.10	Colachel	0.30	Enayamputhenthurai	0.19
Azhikkal	0.09	Keezhakadiapattinam	0.14	Eraviputhenthurai	0.25
Chinnamuttom	0.12	Keezhamuttom	0.10	Eraymanthurai	0.11
Kanyakumari	0.18	Kodimunai	0.17	Ezhudesam	0.17
Keezhamannakkudy	0.09	Kottilpadu	0.15	Helen colony	0.10
Kesavanputhenthurai	0.08	Kurumpanai	0.14	Keezhamidalam	0.12
Kovalam	0.14	Melakadiapattinam	0.15	Kurumpannai	0.11
Manakudy	0.13	Melamuttom	0.11	Marthandanthurai	0.20
Pallam	0.09	Periyavilai	0.07	Melmidalam	0.11
Periyakadu	0.06	Puthoor	0.12	Mullurthurai	0.09
Pillaihooppu	0.09	Simon Colony	0.14	Neerodi	0.18
Pozhikkarai	0.07	Vaniyakudi	0.12	Poothurai	0.12
Puthenthurai	0.07			Ramanthurai	0.11
Puthugramam	0.05			Thoothoor	0.17
Rajakkamangalam	0.13			Vallavillai	0.18
Siluvai Nagar	0.04				
Vavathurai	0.09				
Average	0.1	Average	0.14	Average	0.15
Total average for 3 Taluks					0.13

ocean currents to shift. One of the main causes of the increase in global temperature is pollution from farming practices, industries, and transportation. This perspective demonstrates how all components are related to one another. Figure 6 explains fishers' perceptions of climate change impacts with detailed attributes.

**Analysis of climate change impacts on fisheries:** According to fishers' perceptions, fishery impacts come next to environmental impacts. From the study of Threspuram village fishermen, fishery parameters are mostly affected by species composition, followed by catch and loss in the fishery. Fishermen claim that, as a result of climate change, important fish breeding seasons along the coast have shifted, and coastal species have migrated to open waters. The fishing season also experienced a significant shift. In

recent years, equipment and craft have significantly damaged by harsh weather events. In response to climate change, more than 50 fishing families from the tsunami colony are growing seaweed in the Thoothukudi area. Over the past ten years, heat waves and flooding have periodically destroyed crops in some seasons. Johnson et al. (2016) conducted an attribute analysis of different parameters and found that the fishery was impacted mostly by species composition and catch. The attribute loss in the fishery inventory and aquaculture was followed by the species composition and catch attributes in the Ramanathapuram district of Tamil Nadu. Shyam et al. (2014) indicated that the fishery was impacted mostly by bycatch in the Alappuzha district of Kerala. The analysis of the resilience indicator for this attribute indicated that fish catch has decreased

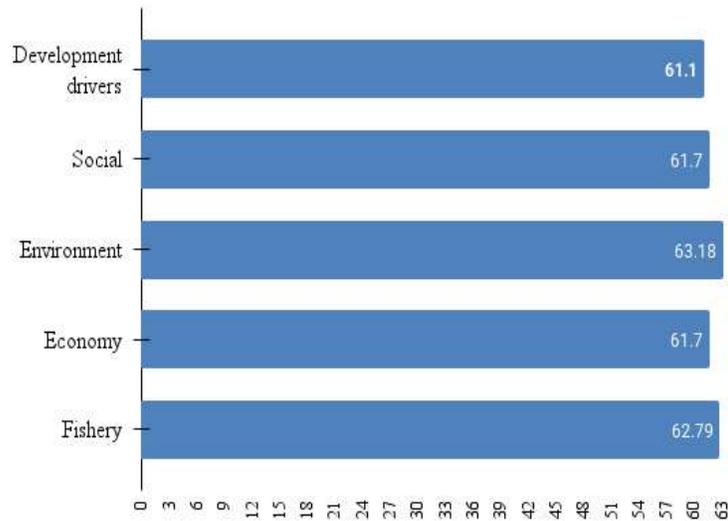
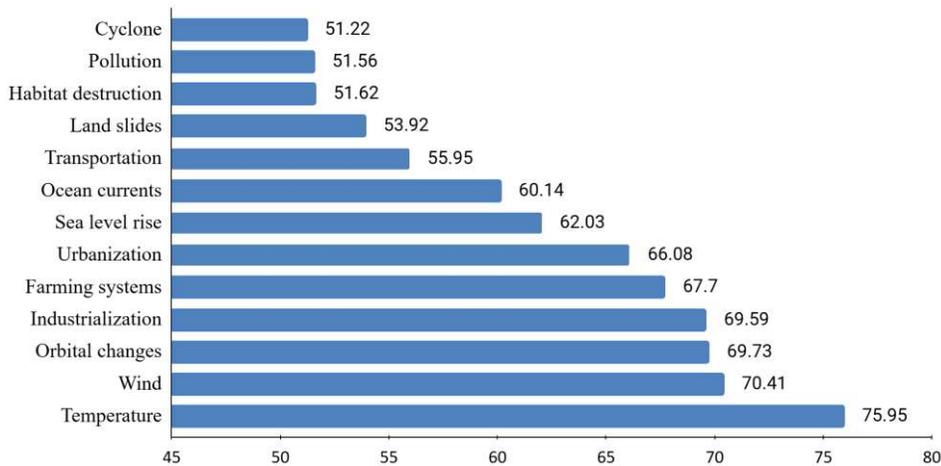


Fig. 4. Fisher's perception of climate change impacts (in percentage)



VI

Fig. 5. Causal factors perceived by the fishermen for climate change (in percentage)

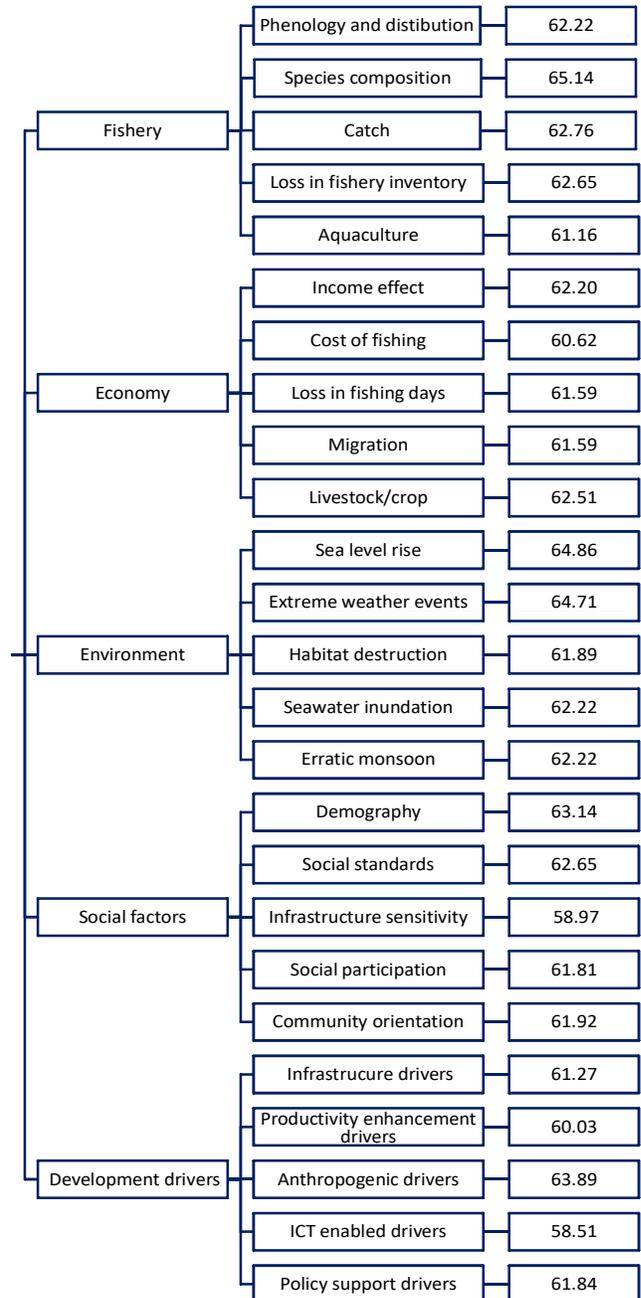
drastically over the years, and that effort has increased fairly. The attributes of phenology, distribution, and species composition followed those of catch.

**Analysis of the impacts of climate change on the economy:** According to fishers' perceptions, economic attributes were impacted next to the fishery in the context of climate change, where livestock and crops were the most limiting factors, followed by income effects, losses in fishing days, and migration. Owing to the shifting fishing grounds and rising fuel prices, fishing has become increasingly expensive. The Food and Agricultural Organization (FAO 2007) found that the doubling diesel price led to a doubling of the proportion of fishers' revenue that they spent on fuel and rendered many individual fishing operations unprofitable, which lends credence to this claim. Reduced income levels, rising living expenses, employment seasonality, and a lack of other pursuits all have an impact on income. Fishermen believe that over the past ten years, there has been a significant decrease in fishery resources. The increased number of boats, unrestricted fishing methods, and the adoption of horsepower-rich engines in boats have caused this drastic decrease. Therefore, there has been an increase in the number of crops and cattle. The least affected feature was the fishing cost. Johnson et al. (2016) and Shyam et al. (2014) revealed that the cost of fishing is the limiting factor for Ramanathapuram and Alappuzha.

**Analysis of the impacts of climate change on the environment:** According to fishermen's perceptions of Threspuram village, the environment is the most affected by climate change. Sea level rise was the most important attribute, followed by extreme weather, while habitat destruction was the least important environmental factor from the data gathered. According to an analysis of the attribute statements, Thoothukudi fishing communities have experienced significant increases in sea level and coastline erosion, which have affected the fishing and related activities of local fishermen. Similarly, previous reports have noted that coastal erosion and rising sea levels have affected fishing and other related activities (Johnson et al., 2016, Shyam et al., 2014). The respondents also felt that there was a noticeable decline in the number of rainy days over time, unpredictable monsoons, significant damage to freshwater sources, and challenging groundwater use as a result of seawater flooding.

**Analysis of the impacts of climate change on social factors:** The fishermen's households had an equal level of conception of the social and economic factors of climate change. The most affected attribute was demography, followed by social standards, and community orientation. Infrastructure sensitivity was the least affected by social participation. Low awareness, limited technical information

exchange, insufficient training programs, and declining social participation among fishers have an impact on social participation. Community group mobilization is extremely uncommon, and there is a dearth of community-based grassroots plans. Social factors strongly impact climate change through infrastructure sensitivity, followed by social participation, community orientation, demography, and social standards of fishers in the Ramanathapuram district of



**Fig. 6.** Attribute analysis of climate change impacts on different parameters (Fishery, economy, environment, social factors and development drivers) (in percentage)

Tamil Nadu (Johnson et al., 2016) while The results from Alapuzha of Kerala have the most impact on social participation, followed by community orientation, social standards, demography, and infrastructure sensitivity (Shyam et al., 2014)

**Analysis of climate change impacts on development drivers:** In Threppuram village that fishermen had the least perception of the development drivers impacting climate change. At the attribute level, anthropogenic drivers scored highest, followed by policy drivers productivity enhancement and ICT-enabled drivers were the least affected in study. The analysis of the statements showed that the majority of the impacts were caused by human activity because of the rise in plastic use associated with coastal tourism and related activities, as well as the growth of residential areas and the disregard for sustainability issues displayed by development activities. In the context of climate change, Ramanathapuram fishermen believed that anthropogenic drivers had the greatest impact on fisheries and productivity enhancement drivers had the least impact (Johnson et al., 2016). Fishermen from Alappuzha believed that policy support drivers had the greatest impact and infrastructure drivers had the least impact on development drivers. Fishers perceived that inadequate cumulative relief and unplanned rehabilitation measures made this district more vulnerable. The study also considered the degree of community involvement and mobilization, alternative career possibilities, awareness, preparedness, and mitigation, as well as the extent of governmental support and requirements. This study underscores the significant impacts of climate change on various attributes, including fisheries, environment, development drivers, economics, and social standards.

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#### CONCLUSION

The fishermen perceive fishery, economic, and environmental parameters as important in climate change adaptation and mitigation plans. Fishermen's awareness level was moderate to poor, indicating that they were unable to relate the environmental changes caused by climate change to their livelihood. Fishermen were vulnerable to unpredictable monsoons and lost fishing days. By incorporating fishermen into planning and preparing for disasters, it is necessary to increase their awareness of

climate change. Additionally, it is suggested that the governance of fisheries must address overfishing and overcapacity, while accounting for socioeconomic characteristics, uncertainty, and sustainability. Resilient fisheries can be achieved by adopting strategies such as co-management or participatory techniques that address the unpredictability, expertise, and dedication of fishermen in diverse places.

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