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Impact of cyclone Tauktae on fishermen's livelihood in Karnataka: A climate change perspective analysis

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Abstract

The Arabian Sea, off India's west coast, is undergoing significant changes due to global climate change driven by rising greenhouse gas emissions and warming waters. This is well evidenced by the increasing frequency of cyclonic events along the coast, with five of the eight cyclones recorded in India since 2019 impacting the west coast. Cyclone Tauktae of 2021 was one of the most severe, with extremely recent cyclonic storms wreaking havoc on India's southern maritime states. This paper examines the extent of damage that happened to households and livelihood-supporting assets, the socio-economic impacts, the social security challenges faced and the preparedness status in Karnataka's coastal districts. This study also highlights the socio-ecosystem changes that occurred, as well as the coping strategies used in the maritime state of Karnataka in the context of climate change and proposes strategic action plans aimed at effectively mitigating the impacts of tropical cyclones.

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Introduction

The alarming changes in the climate are affecting life both above and below the water in many ways. Though the climate change concept took a while (from Stockholm Conference in 1972 to Kyoto Protocol in 1997), to gain widespread recognition (Jackson, 2007), its impacts in various spheres of life are extremely evident and extensively pondered (Guggisberg, 2018; Wieb *et al*., 2019; Dominik and Karin, 2023). Increased atmospheric temperature due to anthropogenic greenhouse gas emissions is the major impact cited by many environmental scientists in earlier climate change research. In recent decades, the scientific understanding of climate change has advanced significantly. Increased heat waves, deluges, and droughts are just a few examples of natural disasters that could result from failing to swiftly eliminate factors causing global warming (Pachauri and Reisinger, 2008; Paramita *et al*., 2022). These detrimental effects of climate change are more common in developing countries than in developed countries (Walimuni *et al*., 2023).

In recent years, climate change has significantly impacted the Indian subcontinent, which has a very diverse terrain and climate due to its proximity to the equator (Picciariello *et al*., 2021). Several climate change hazards have been identified by various studies, including an increase in the incidence of heat waves, reduced working hours, challenges in regulating core body temperatures and a considerably warmer, more humid coastal belt (Kjellstrom *et al*., 2017; Mani *et al*., 2018; Rohini *et al*., 2019; Golechha and Panigrahy, 2020; Zhang *et al*., 2021). It is estimated that over 50% of Indians currently live in climate hotspot regions and work in climate-sensitive sectors like agriculture and fisheries. By 2050, 148.3 million Indians are projected to reside in extreme climate hotspots (Mani *et al*., 2018).

Given that India has more than 7,500 km of coastline with numerous dense coastal settlements that rely on capture fisheries as their primary source of income, the socio-ecological effects of climate change are much more severe in coastal areas (Sarthi *et al*., 2014; Swapna *et al*., 2020). With increased sea surface temperature, the ocean poses a severe direct threat to life beneath the water and sea level rise and extreme weather events are the main threats to coastal life. Another effect of climate change is the increased vulnerability of coastal regions to tropical cyclones and their destructive impacts through storm surges, torrential rain, runoff, erosion and devastating floods (NRC, 2010). The Indian subcontinent is exposed to nearly 10% of the tropical cyclones in the world, with an average of five to six every year (NDMA, 2023). The primary devastation in coastal areas caused by disastrous events includes loss of fishing days, damage to transport boats, fishing gears and equipment, motors as well as common facilities like harbours, net mending units and other essential infrastructure (FAO, 2018). Under many future climate change scenarios, tropical cyclone frequency and magnitude are expected to grow (Noy, 2016). India witnessed more cyclones on its eastern coast than on its western coast. But in recent years, the tropical cyclonic incidence along the Arabian Sea coast has also shown an increasing trend (Kar and Banerjee, 2021). A recent study (Ghai, 2023) reveals a significant 52% rise in the frequency of cyclonic storms along India's west coast. Notably, before the occurrence of Cyclone Tauktae, this region experienced two other cyclones in consecutive years: Cyclone Vayu in 2019 and Cyclone Nisarga in 2020. Cyclone Tauktae, a tropical cyclone that originated in the Arabian Sea, made landfall on the Gujarat coast on 17 May 2021 and significantly impacted major maritime states along the west coast of India. It was the most intense cyclone to strike the Indian coast between 1961 and 2021, classified as a Very Severe Cyclonic Storm (VSCS). Karnataka was one of the coastal states that was adversely affected by the Cyclone Tauktae. The present study aims to assess the socio-economic impact of the Cyclone Tauktae on the livelihoods of the marine fishing communities residing in the three coastal districts of Karnataka, along with the perceived adaptation and mitigation strategies.

Materials and methods

The research was conducted in three coastal districts of Karnataka state, namely Dakshina Kannada, Udupi and Uttara Kannada, which were severely impacted by the Cyclone Tauktae. A data collection tool was developed to examine the effects of Cyclone Tauktae, spanning social (life security measures, loss of fishing days, damage to roads), economic (average monthly income, type of fishing craft, types of fishing gear) and demographic (place/district, gender, household type, educational level and cultural factors) dimensions to capture the damage caused by the extreme weather event. Additionally, it assisted in gathering data on governance and adaptive responses, which show how the social system responded to it. The validity of the items in the assessment instrument was evaluated using the opinions of experts (working in the domains of climate change and related research). A few chosen respondents were pretested with the validity-checked schedule (initially written in English) to gain their feedback and validate its reliability. After pretesting, the questions were modified for the respondents' benefit and translated into Kannada to gather data. We used a licensed version of SurveyMonkey software as a survey design platform for the online data collection approach. Survey collectors (links for collecting the responses), compatible with smartphones and computers, were sent to selected respondents. Using a random sampling approach, the entry point respondents were chosen based on the Tauktae-affected sample frame from each district. A snowball sampling was followed further to send the survey collectors to another respondent. Thus, a total of 108 fishermen and women representing different fishermen families participated in the current study. Frequency and percentage were used to summarise the demographic data and major social security problems observed in coastal districts of Karnataka due to the cyclone Tauktae which were identified using Likert's scale and data was analysed using Fried-man two-way ANOVA. Similarly, the socio-ecosystem changes and coping strategies followed in the state were assessed using a four-point scale ranging from 0-25% to over 75%.

Results and discussion

Demographic information of the participants

Among the 108 respondents (representing different households), 58.3% were from the Dakshina Kannada District. Udupi and Uttara Kannada had 34.3 and 7.4% of respondents respectively (Table 1). The average age of the participants was 43 years. Of the respondents, 10.2% were males and nearly 80.0% were females. About 67% of the respondents lived in tiled houses, while 28% resided in concrete houses. Similarly, 67 respondents reported having cyclone proofing for their houses, whereas 37.4% had no cyclone proofing. Among the concrete houses, 20 had cyclone proofing, whereas in the tiled households, only 39 out of 67 had cyclone proofing. In terms of education, 35.2% of respondents had completed high school level of education, followed by 23.1% with primary school education. It was also noted that 10% of the respondents were graduates, while approximately 15.7% had no formal education (Table 1). Fishing was the primary source of income for more than 97% of the respondents with an average of 20.28 years of fishing experience.

Table 1. Demographic attributes of participants in the study (n=108)

Attributes	Sub-attribute	%
Place/District	Dakshina Kannada	58.3
	Udupi	34.3
	Uttara Kannada	7.4
Gender	Male	10.2
	Female	88.0
	Not revealed	1.80
Household type	Concrete	28.0
	Tiled	67.0
	Other	5.0
Educational Level	No formal education	15.7
	Primary school (1-4)	23.1
	High school (5-10)	35.2
	Higher secondary	15.7
	Degree	6.5
	Post-graduate and above	2.8
Occupational status	Fishing	97.0
	Allied activities in fishing/farming	3.00

Marine fishing and livelihood

The Karnataka coast is home to 162 marine fishing villages, with 22 located in Dakshina Kannada, 54 in Udupi and 86 in Uttara Kannada (CMFRI-DoF, 2020). The respondents from the study location reported an average of 832 active fishermen per village. District-wise distribution showed that Dakshina Kannada District has an average of 765 fishermen per fishing village. The highest number of fishermen per village was reported in Udupi District (1020), while the lowest was in Uttara Kannada District (556). Over half of the households surveyed earned less than ₹10,000 monthly (Table 2). Nearly 30% of those engaged in fishing as a means of livelihood relied on boats equipped with a single outboard motor for their fishing operations. In addition, more than one-third of fishermen had gillnets as their primary fishing gear. On average, 15 persons were going in mechanised fishing boats (Table 2). Crew sizes were reported to be 9 and 8 for motorised craft with more than one outboard motor and motorised craft with one outboard motor respectively.

Impact of Tauktae Cyclone in coastal districts of Karnataka

Characteristics and nature of hazard: The nature of the hazard was examined in three coastal districts of Karnataka based on the observations of the respondents. The two most significant features of cyclone Tauktae as reported by more than 80% of respondents were strong winds and storm surges. The most severe hazard of cyclone Tauktae reported in the Dakshina Kannada District was the storm surge (Table 3). However, the strong wind was the main feature of the Tauktae Cyclone observed in the Udupi District. At the same time, cyclone Tauktae was felt in Uttara Kannada District, with violent rain, strong winds and storm surge, as reported by 87.50% of respondents. Reports of IMD (2021) also showed the same pattern as reported by the respondents in this study. As the cyclone tracked parallel to the west coast, it brought heavy to extremely heavy rainfall, strong winds, and tidal waves. It impacted Lakshadweep on the 13-14 May 2021, Kerala on the 14-15 May, Karnataka on 15 May, Goa and Southern coastal Maharashtra on the 15-16 May, and Northern Maharashtra on 16-17 May 2021, continuing in this manner along the coast.

Table 2. Respondents' distribution with respect to marine fishing and livelihood (n=108)

Attributes related to fishing	Measurement level	%
Average monthly income (₹)	<5000	29.6
	5000-10000	38.9
	10000-20000	17.6
	20000-30000	12.0
	>300000	0.95
	Not willing to reveal	0.95
Type of fishing craft	Mechanised	21.3
	Motorised (with > one outboard motor)	16.0
	Motorised (with one outboard motor)	28.7
	Motorised (inboard motor)	08.5
	Non-motorised	22.3
Types of fishing gears	Trawl	18.5
	Bagnets	15.7
	Gillnets	34.3
	Hook and Line	05.6
	Seines	11.1

Previous studies on climate mitigation in coastal areas clearly stated that the presence of mangroves and casuarina plantations, among other things, would act as a natural cyclone proof along the coastal areas, particularly during times of sea surge and coastal inundation (Das, 2007; McIvor *et al*., 2012; Md. Danesh *et al*., 2013; Das and Sandhu, 2014; Krauss and Osland, 2019; Das, 2022). The present research looked into the status of such traditional cyclone-proofing along Karnataka's coastal districts. More than half of respondents (52.4%) said sea walls are available in their villages and nearly 48% of the respondents reported they do not have sea wall protection. Among the respondents of the study, 77.8% were from villages with mangrove habitats. Similarly, 26.9% of respondents said casuarina plantations exist in their villages. According to the participants, the width of mangrove forests and casuarina plantations has decreased in some coastal districts of Karnataka compared to historical data

Socio-economic losses due to cyclone Tauktae: In the aftermath of the cyclone, the coastal community reported a total of 9 fatalities caused by the hazards and related externalities, while an additional 4 individuals were reported missing. Cyclone Tauktae injured up to 1007 people in the coastal village. In Karnataka's Dakshina Kannada, Udupi and Uttara Kannada maritime districts, the average loss in total fishing days reported was 31, 39 and 22 days, respectively (Table 4). The economic loss per household in coastal communities due to the Tauktae Cyclone was estimated as ₹102090.90. Among the three coastal districts, the Uttara Kannada District suffered the greatest economic loss, with an average loss of ₹287142.86 per household. In the Udupi District, the cyclone caused significant economic damage (₹126060.61 per household). The average economic loss reported at the household level in the Dakshina Kannada District was ₹66728.81. The cyclone damaged an average of 1.79 km of road in the coastal villages of Udupi District. At the same time, the Uttara Kannada and Dakshina Kannada districts reported 0.50 and 1.16 km of road damage per coastal village, respectively (Table 4).

*Extent of damage to household and livelihood-supporting items:*The extent of damage to household and livelihood-supporting items were assessed using a three-point continuum (Partially damaged, Completely damaged and Not affected). Seventy-five percent of

Table 3. Characteristics of the Tauktae Cyclone reported in coastal districts of Karnataka (n=108)

District	Violent rain		Flood		Wind		Landslide		Storm surge	
	f	%	f	%	f	%	f	%	f	%
Dakshina Kannada	55	87.30	8	12.70	56	88.89	1	1.59	58	92.06
Udupi	24	64.86	7	18.92	27	72.97	0	0.00	24	64.86
Uttara Kannada	7	87.50	4	50.00	7	87.50	1	12.50	7	87.50

Table 4. Estimate of socio-economic losses due to Tauktae Cyclone (n=108)

Attributes	Measurement level	Dakshina Kannada	Udupi	Uttara Kannada
Life security	Death reported (Nos.)	5	3	1
	Highly injured people (Nos.)	13	11	1
	Missing persons (Nos.)	3	1	0
Fishing days	Loss in fishing days (Nos.)	31	39	22
Economic loss	Average economic loss (₹)	66728.81	126060.61	287142.86
Damage to roads	Loss of road (km)	1.16	1.79	0.50

Uttara Kannada District respondents reported partial damage to their homes. Similarly, 52.4 and 43.2% of respondents reported partial damage to their homes in the Dakshina Kannada and Udupi districts. About 3% of Dakshina Kannada respondents and 2.7% of Udupi respondents reported complete house damage. The cyclone had no effect on the roads in the Udupi District, according to 59.5% of respondents (Fig.1).

However, 12.5% of respondents in Uttara Kannada District reported that the cyclone completely destroyed roads in their villages. Similarly, 25% of Uttara Kannada District respondents reported the cyclone completely destroyed their village's water supply arrangement. According to the survey, a significant proportion of respondents in the Dakshina Kannada, Udupi and Uttara Kannada districts (14.3, 18.9 and 25.0%, respectively), reported that their fishing boats suffered complete damage. More than 70% of respondents from Dakshina Kannada and Udupi districts reported that their fishing nets had been entirely or partially damaged (Fig. 1). According to GoI (2021) report, in Karnataka a total of 263 fishing boats and 324 fishing nets were damaged.

Major social security problems observed in coastal districts of Karnataka due to Tauktae

Respondents were asked to rank the most serious problems they encountered during the Tauktae cyclonic period (Rank one being the most serious problem) (Fig. 2). During the cyclonic period, the most severe problem faced by the coastal villagers of Karnataka was the lack of transport facilities (mean rank=3.64). Many villages reported complete or partial damage to the roads. As a result, the affected villages were temporarily isolated. Power shortage was another significant issue (mean rank = 3.73). Respondents from the coastal villages of Karnataka also identified fuel scarcity (mean rank = 3.94) and lack of drinking water (mean rank = 4.4) as major issues. At the same time, respondents ranked food insecurity (mean rank =5.57) and lack of other supplies (mean rank =5.24) as the two most minor concerns during that time period (Fig. 2). This may be because of the extraordinary measures taken by the state and district governments to ensure that no one went hungry. Eight relief camps were established throughout three coastal districts in Karnataka in the wake of Cyclone Tauktae, housing approximately 10,000 people and offering food and basic amenities. For coordinated rescue and relief activities, about 1,000 trained members of the Fire and Emergency Services Department, Police, Coastal Police and House Guards were sent in. The district administrations in Uttara Kannada, Dakshina Kannada, and Udupi received grants totaling ₹12 crore, ₹60 crore and ₹23 crore respectively, from the State Disaster Management Authority to help lessen the effects of the cyclone and provide aid to people in need (Madhanagopal and Jacob, 2022).

Based on the district-level analysis, it was found that power outages (mean rank = 3.39) was the most severe problem encountered by the villages in the Dakshina Kannada District during the cyclone Tauktae (Table 5). The lack of fuel (mean rank = 3.75)

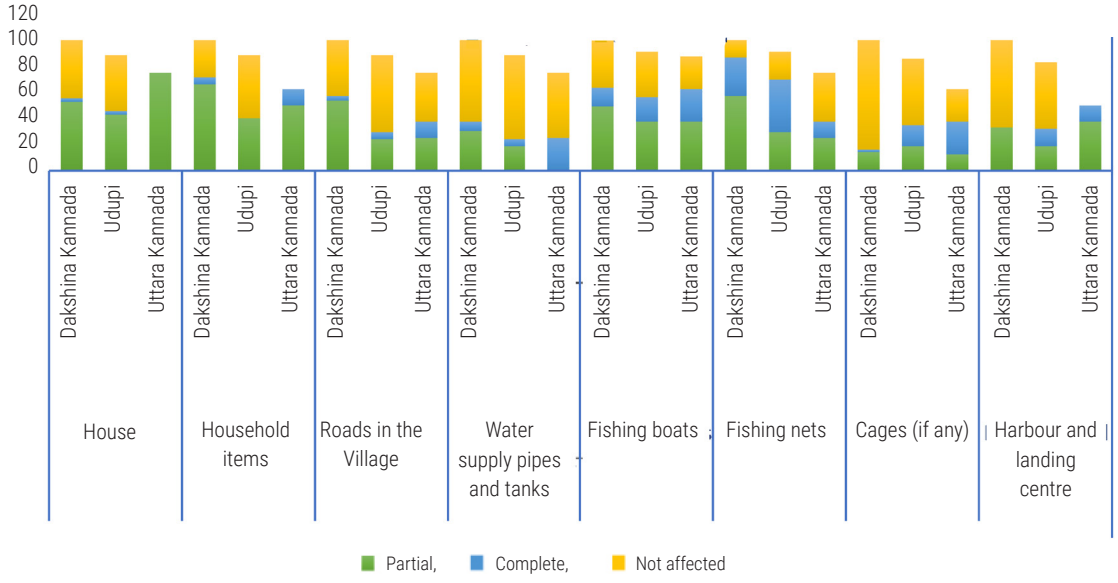

Fig.1. Extent of damage to household and livelihood-supporting items

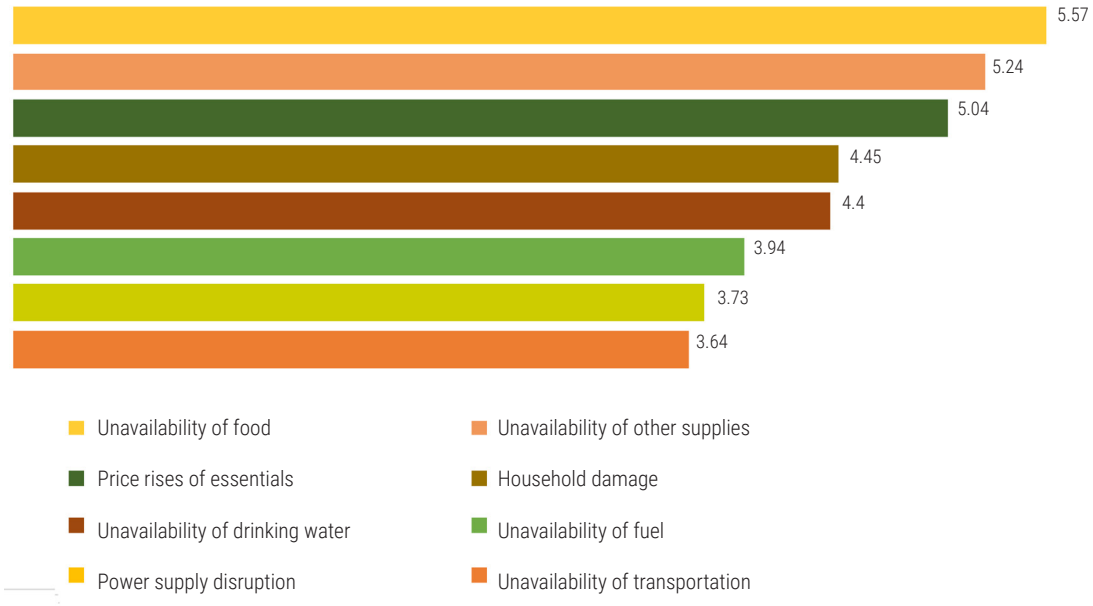

Fig. 2. Major social security problems perceived by the respondents in coastal districts of Karnataka

Table 5. District-wise analysis of social security problems observed due to the Tauktae Cyclone (n= 108)

Problems	Mean Rank		
	Dakshina Kannada	Udupi	Uttara Kannada
Unavailability of transportation	3.84	3.24	3.86
Unavailability of drinking water	4.41	4.48	3.86
Unavailability of food	6.04	4.91	5.00
Unavailability of fuel	3.75	4.06	4.86
Unavailability of other supplies	5.13	5.18	6.43
Power supply disruptions	3.39	4.39	3.29
Price rises of essentials	5.25	4.61	5.43
Household damage	4.20	5.12	3.29
Chi-Square	52.607	15.485	10.190
Asymp. Sig.	.000**	.030*	.178NS

**Significant at 0.01%, *Significant at 0.05%, NS=Non significant

and transportation (mean rank = 3.84) were the subsequent most significant challenges faced by the affected communities. The government ensured food availability and price stability of essentials, as evidenced by respondents' ratings. The most serious problem faced by the villagers in the Udupi District was damage to transport facilities (mean rank = 3.24). The villagers of the Udupi District rated unavailability of other supplies they encountered (mean rank = 5.18) and household damages as the least severe Tauktae cyclone-induced problems. The difficulties faced by the villages in Uttara Kannada District due to the Tauktae cyclone did not differ significantly in severity. According to the villagers, the two most serious issues were household damage and power outages (both with a mean rank of 3.29).

Preparedness status in coastal districts of Karnataka during Cyclone Tauktae

According to the survey, 80% of respondents reported being regular users of climate-related information disseminated by various agencies, while 20% indicated that they did not receive climate-related information consistently. According to respondents, there were various sources of early information about cyclone Tauktae, such as the Department of Fisheries, INCOIS, neighbourhood updates, mass media, the Meteorological Department, social media channels, television, newspapers, online news channels, GPS messages and the Karvali police. About 86.1% of respondents received cyclone warnings ahead of time from their information providers, while 13.9% did not receive a cyclone warning in advance. Even though most of the respondents received a cyclone warning in advance, 81.5% stated that they could not relocate valuable assets to a safe location before the cyclone's arrival. Regarding the relief centres in each village, respondents informed that each village had one relief camp on average. During the cyclonic period, some villages had up to four relief centres. Only 34.3% of respondents were evacuated before the cyclone (Table 6). The health facilities available to relief camps and villages during the cyclone were insufficient, with 50.9% reporting that they did not receive any healthcare. Similarly, although they all lived in disaster-prone areas, most respondents (77.8%) had received no training in dealing with natural disasters. Similarly, majority of respondents (74.1%) did not receive either relief articles or compensation (77.8%) to aid them in recovering from the cyclone's impact (Table 6).

Socio-ecosystem changes and coping strategies in Karnataka under the climate change perspective

An effort was made to capture perceived changes in livelihood and social security components because of long-term climate change and the coping mechanism followed to mitigate the impact of tropical cyclones along the coastal belt in Karnataka (Fig. 3). The majority of respondents (59.3%) indicated a decline in crop yield of 0 to 25% due to climate change-related events in their area. However, 15.7% of the respondents reported a significant decrease in crop yield of 51-75%. The study suggests that variations in perceptions

Table 6. Preparedness observed during the cyclone Tauktae in coastal districts of Karnataka (n=108)

Preparedness factors	Measurement level	Dakshina Kannada	Udupi	Uttara Kannada	Total (%)
Are you getting weather-related information daily?	Yes	54	28	4	79.6
	No	9	9	4	20.4
Did you receive the cyclone warning in advance?	Yes	54	34	5	86.1
	No	9	3	3	13.9
Could you able to shift valuable assets to a safe place?	Yes	9	7	4	18.5
	No	54	30	4	81.5
Are relief centres and facilities available?	Yes	63	37	8	100.0
	No	0	0	0	0.0
Have you been evacuated to the cyclone shelter?	Yes	20	13	4	34.3
	No	43	24	4	65.7
Is health care available?	Yes	27	21	5	49.1
	No	36	16	3	50.9
Whether you have received any training in handling natural hazards?	Yes	18	5	1	22.2
	No	45	32	7	77.8
Did you receive any relief articles?	Yes	15	9	4	25.9
	No	48	28	4	74.1
Did you receive any compensation?	Yes	16	7	1	22.2
	No	47	30	7	77.8

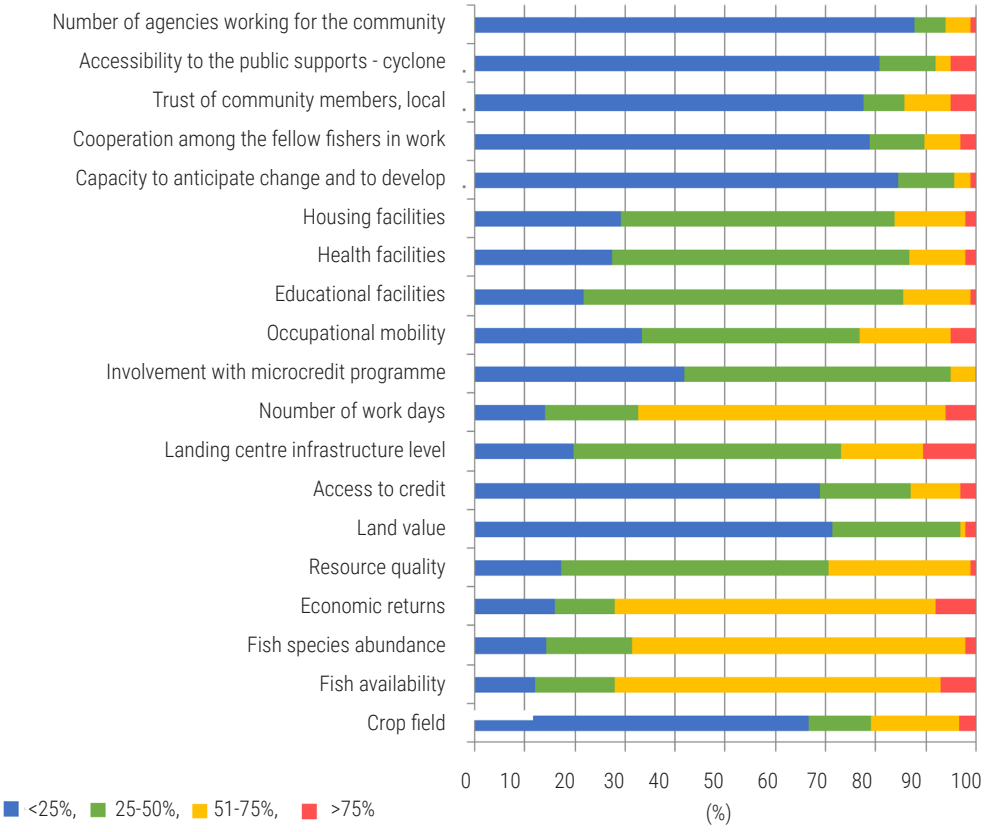

Fig. 3. Socio-ecosystem changes observed in Karnataka

of climate change impacts may stem from the differences in the reliance on crop cultivation as a secondary source of income. However, 60.2% of the respondents reported a 51-75% decline in fish availability due to climate change-related events. Similarly, majority (63%) observed a decline in fish diversity or abundance ranging from 51 to >75%. Around 66% of respondents indicated a quality loss of less than 50%, suggesting that the overall changes in the quality of the available resources have been relatively modest. Most respondents claimed a significant decline in economic returns attributed to the effects of climate change. Specifically,

60% of respondents indicated a reduction in financial return ranging from 51 to 75%, while approximately 8% reported a decline of over 75% (>75 to 100) (Fig. 3). The total number of working days available in the marine fisheries sector of Karnataka has decreased dramatically due to climate change-related phenomena. According to 70% of respondents, climate change has resulted in more than 50% reduction in the total number of workdays. Similarly, changes in the value of livelihood assets and asset-related facilities revealed that land value and access to credit experienced a less severe decline than other items. Almost 65% of respondents reported no or little change in land value because of the adverse climate effect (0 to 25%). A similar pattern was observed in the case of credit facility access. Sixty-three percent of respondents opined that the landing centre infrastructure showed a moderate level of reduction (25 to 75%) due to climate change-induced damage.

The study also examined life-supporting and sustaining facilities such as education, healthcare, housing and social bonding in the context of climate change-induced phenomena. The majority of the respondents opined that these facilities experienced only a moderate reduction in their villages. They observed similar trends with respect to occupational mobility, educational access, healthcare services, and housing facilities. Overall, climate change-related impacts did not significantly hinder social mobility, cooperation or group activities among the respondents. The respondents' coping strategies were examined to determine the adoption pattern of adaptation and mitigation practices during tropical cyclone incidents (Table 7). Borrowing/taking credit to meet the financial loss incurred during the cyclone was the most preferred coping strategy among the respondents (87%). Selling assets and migrating to other locations were the least preferred mitigation and adaptation strategies (both with 81.5%). Regarding coping strategies, most respondents (80.6%) favoured indigenous cyclone prediction methods and 82.4% expressed a desire to better understand cyclone warning signals. Most respondents were hesitant to alter their savings and eating habits as coping mechanisms (Table 7). Other commonly preferred coping strategies included strengthening houses (74.1%), installing life-saving devices in their crafts (73.1%), attending more training classes (67.6%) and selling labour for advance payment (63%).

Table 7. Climate change coping strategies followed in Karnataka

Items	Yes		No	
	f	%	f	%
Indigenous cyclone prediction	87	80.6	15	13.9
Understanding cyclone warning signals	89	82.4	12	11.1
Income diversification activities	29	26.9	72	66.7
Precautionary food saving	22	20.4	79	73.1
Precautionary money saving	24	22.2	77	71.3
Reducing food consumption per day	37	34.3	64	59.3
Selling labour for advance payment	68	63.0	32	29.6
Selling of assets	12	11.1	88	81.5
Borrowing/credit taking	94	87.0	7	6.5
Migration to other places	13	12.0	88	81.5
Attending more training classes	73	67.6	28	25.9
Repair (strengthening) house	80	74.1	21	19.4
Installing life-saving devices in the craft	79	73.1	23	21.3

The west coast of the Indian subcontinent has historically been less affected by cyclones compared to the east coast. As a result, when cyclone Tauktae hit the West coast, the impact was severe due to a lack of preparedness to deal with climate change-related events (Vohra, 2021). The results of the present study corroborate the same. Though cyclone warnings were disseminated through various means and reached most of the respondents, the low level of preparedness, especially the the limited response time, prevented many from relocating household items to safer places. Similarly, more than 75% of respondents reported that they did not receive any relief materials or compensation. In the context of rising frequency of cyclonic events and associated losses, the immediate question to be answered is, how can we better manage tropical cyclones and mitigate their impacts? A critical aspect of this is educating and preparing communities to respond effectively to cyclones, such as making their homes cyclone-proof, using survival kits, ensuring safe evacuation procedures and maintaining health and hygiene standards at relief centres. Identifying and addressing any anthropogenic factors that may contribute to the cyclonic impact in the area is also critical. Efforts to improve the adaptation capacity of the social systems from the climate change perspective are crucial. These efforts could include a codified early information dissemination and cyclone warning system, expansion of natural protective barriers such as mangroves and casuarina trees and empowerment of local communities through proper and timely training to effectively manage climate change impacts. Furthermore, identifying site-specific adaptation and mitigation practices, ensuring their proper execution and providing policy support is vital to strengthening community resilience against climate change-related challenges. Since, the indigenous cyclone prediction methods and the understanding of cyclone warning signals have emerged as effective coping strategies, integrating these indigenous knowledge systems with scientific forecasting methods could significantly enhance the efficacy of early warning systems and risk communication efforts.

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