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RESEARCH PAPER

Fishers on the First Mile: Early Warning Early Action by Traditional Fishers of Southwestern India

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Abstract

Changing, uncertain, and extreme weather in a warming world is making fishing increasingly risk-prone. As climate change intensifies tropical storms and increases the frequency of extreme weather events over the Eastern Arabian Sea, effective early warning and early action are critical for traditional fishers. This study, conducted in Thiruvananthapuram district in southwestern India, examines how fishers respond to early warnings in their work environment. Over 50,000 seagoing fishers in the area engage in a range of artisanal fishing practices, including: (i) shore-seining; (ii) raft fishing with nets near the coast; (iii) fishing on 10-meter fiberglass boats with nets or hook-and-line at distances of 5–100 km; and (iv) ring seining using 12–14-meter mechanized vessels at 10–200 km from shore. The qualitative, field-based study draws on focus group discussions, interviews, and informal conversations with 50 fishers across five villages, as well as insights from 10 key informants and experts. Findings highlight the need for seamless weather forecasts at multiple time scales, better aligned with early warning and early action needs, as well as more localized and context-specific weather information relevant for diverse fishing operations. The study also calls for stronger community engagement and rigorous training to promote effective early action in the last mile.

Keywords: traditional fishing, shore waves, marine weather, marine forecasts, swell, Easter Arabian Sea, storm trends, climate change, early warning, early action

1. Introduction

Global warming is marked by a trend of intense tropical cyclones in the Eastern Arabian Sea (Murakami et al. 2017, Panickal et al. 2022, Nirmal et al. 2023) and dangerous sea states associated with storms near and far (Remya et al. 2016, INCOIS 2024). One of the places where traditional fishers have been in the news of late due to their exposure to climate impacts is the Thiruvananthapuram district, the capital of Kerala state on India's southwestern coast. The district is home to over 50,000 artisanal fishers in 42 villages spread along a 79 km coast.

The coast is lined with sandy shores, seawalls, and rocky cliffs. estuaries and eroded beaches with granite seawalls. The local fishers mostly use small boats of about 10 meters (m) in length and even smaller canoes and rafts. They engage in hook-and-line, shore seine (pulling ropes on either end of a long, baggy net immersed in an arc close to the shore), boat seine, or net fishing (Martin et al. 2022). Usually, they fish close to the shore, but some of the motorized boats and larger ring seine boats go as far as 200 km from the shore. These craft are vulnerable to winds of over 40 kilometers per hour (40 kmph — about 22 knots), denoted as a strong breeze on the Beaufort Scale, that can produce waves of 3 m in height (WMO, 1998).

This report looks at how traditional fishers act on weather forecasts and early warnings that often come with forecasts. Set in their work environment, the study looks closely at early action options and challenges that the fishers face. This introduction sets the context of the study, its background of weather-related hazards, and the changing nature of risks they pose, and it explores how regular forecasts, especially during the monsoon season, increasingly include early warnings. The following section describes the research approach and defines the research questions, and the one that follows lists the research methods. Then, the findings section shares the research outcomes. Further, the discussion section looks at the broader implications of the findings, and the report concludes with a few takeaways.

The sea state: The Eastern Arabian Sea is known for its diverse and hazardous wind and wave regime, especially during the monsoon season from June to September. While strong southwesterlies prevail during May–September, it is northeasterlies that dominate during November–February. Wave patterns differ across seasons and are influenced by the wind, ocean currents, and other factors such as storms in different oceans. Monsoon winds whip up high waves that can be risky for the fishers (Shanas et al. 2024). As such, the annual mean wave height of 1.23 m in the Eastern Arabian Sea is higher than that in the western part of the sea (0.9–1.1 m), and during the monsoon, it is even higher (Kumar and Sivakrishnan 2023).

Before the monsoon, long-period swells from storms and sustained wind in the Southern Indian Ocean or South Atlantic reach the southwestern shores (Remya et al. 2016; Kumar and Sivakrishnan 2023). They can take four to six days to traverse about 10,000 km to reach here (INCOIS 2024). They come from the southwest during the non-monsoon season and from the west-southwest during the monsoon season (Shanas et al. 2024). Unlike the choppy surface waves, these smooth rolling waves are less affected by the local winds. They pack in more energy than the short-lived local waves and break and crash onto the seashore, crushing habitats and infrastructure.

Intensifying storms: Of late, storms over the Eastern Arabian Sea just before and at the start (March–June) and after the monsoon (October–December) have become more intense (Murakami et al., 2017; Panickal et al., 2022; Nirmal et al., 2023). A recent analysis (Nirmal et al. 2023) showed a clear increase in the frequency of tropical cyclones having a maximum sustained wind (MSW) speed of more than 62kmph (34 knots – the point at which IMD declares cyclones with a clear early warning early action protocol). More weather systems were developing into cyclones during 2001-2021 compared to an earlier period of 1979-2000, the study noted. This intensification is due to the warming of the upper ocean and the presence of more humidity in the lower atmosphere in a changing climate (Nirmal et al. 2023).

Post-monsoon storms, especially, are gaining strength. An extremely severe cyclonic storm (ESCS – maximum winds above 168 kmph) was recorded for the first time in the season in October 2014. The post-monsoon season of 2015 saw two consecutive ESCSs. There were five cyclonic events in the post-monsoon season of 2019, with an ESCS briefly blowing along with a super cyclonic storm (above 222 kmph). Such a coincidence was reported for the first time in the satellite era, that is, since 1961 (Nirmal et al. 2023). This new trend, dramatically marked by Cyclone Ockhi of 2017, has prompted the national forecaster IMD to deploy new technologies to better detect, track, and forecast storms (Bhardwaj and Ganguly 2023).

While the Indian Ocean remains the warmest, its recent warming trend is very prominent in its western parts, including the Arabian Sea, with a mean summer sea surface temperature (SST) rise from 26.5 degrees Celsius to 28 degrees Celsius over the past century (Roxy et al. 2014). Over the warming ocean, cyclones not only live longer but also gain strength rapidly. Cyclone Ockhi formed in the Bay of Bengal in November 2017 is an example of this rapid intensification into a very severe cyclonic storm (118–166 kmph) and an unusually long track of 2500 km over nine days (Panda et al. 2022). It claimed over 365 fishers' lives off the shores of south India (Hindustan Times 2018).

Fishing as a risky activity: Fishing as such is risky in this region. From May onwards, when the monsoon gains strength, there are frequent accidents and incidents, especially close to the shore in the wave impact zone (SIFFS 2017). Media reports that 345 more fishermen died while fishing off the shores of Kerala state during 2016 –2021 – 145 of them in Thiruvananthapuram (Kumar 2021).

Ironically, monsoon is also a season of good fish catch. A combination of factors brings more fish close to the shore. These factors include the upwelling of cool, nutrient-rich water (Gupta et al. 2016), flow of sediments from rivers and, as the local fishers say, the monsoon winds churning the sea and the rains cooling it down. Besides, during the monsoon, there is no mechanized fishing. It is the fish breeding season, and only traditional fishers are allowed to fish during this season. This gives traditional fishers exclusive access to many local markets. As such, uncertain income, seasonal catch, and a highly perishable product with little local storage facilities make artisanal fishing a precarious livelihood activity here (Martin et al. 2022). In such a context, fishers are usually reluctant to let an opportunity to get a good catch go to waste.

The role of marine forecasts: Forecasting and early warning systems analyze and identify potential weather- and climate-related risks and hazards and enable early action. Weather forecasts inform people what the weather will do in the future – in different scales of times. Forecasters make these calculations in three steps: observations, calculations about the future, and giving details based on meteorological expertise (Met Office 2024). Some of the weather events can be potentially hazardous for different groups of people. They merit early warnings.

An early warning informs people about hazardous weather or climate-related events ahead and advises action by governments, communities, and individuals to minimize their impact. Early warnings are a cost-effective tool that saves lives and reduces economic losses (WMO 2024). They save and protect lives, livelihoods, and assets of people at risk (WMO 2024). Marine forecasts and early warnings play a key role in reducing risks involved in fishing – and thereby minimize human suffering and the cost of responses (Finnis et al. 2019, Wilkinson et al. 2018).

IMD Cyclone Warning Centers issue port warnings and coastal bulletins for ocean parts up to 75 km from the seashore and sea area bulletins for distances beyond 75 km. Special warnings are usually issued for fishermen four times a day and eight times when the sea is rough. State government officials warn coastal residents through local offices and broadcast warnings through All India Radio and the national television Doordarshan and other media channels (RMC 2024).

Traditional fishers largely depend on television and radio news for weather forecasts and early warnings. During the monsoon season, IMD frequently issues weather alerts along with high wave alerts given by the Indian National Centre for Ocean Information Services (INCOIS). IMD also issues early warnings about high wind events and storms in the Arabian Sea. These warnings also include maps and tracks of approaching storms. A key part of these early warning messages is often an advisory restricting fishing for the entire 582 km coastline of Kerala state.

Meanwhile, INCOIS offers district-level information on wind and waves on its website and through community weather services. Several such services run by charities and research institutions relay weather bulletins and early warnings over mobile phone text, voice, and software applications. Of late, fishers increasingly use the internet, software applications, and social media for forecasts (Martin et al. 2022). In conversations, fishers said they frequently sought weather information online and shared notes with young fishers who are knowledgeable about international weather applications (e.g., Windy and Accuweather).

Even while using multiple forecast sources, traditional and local knowledge, experience, and real-time visual observations, fishers often disregard forecasts and alerts when there are prospects of a good catch and go fishing (Martin et al. 2022). Fishers have limited use of marine forecasts for several reasons, as local research suggests. First, there is an apparent gap between what scientists and forecasters think as useful forecasts and what fishers actually find usable (Baily et al. 2012, Lemos et al. 2012). This gap has been attributed variously to inefficient communication, lack of appreciation by users, and the sheer necessity to keep fishing in a precarious, seasonal, and inherently risky job (Hov et al. 2017, Attwood 2018, Martin et al. 2022). As such, the levels of forecast and early warning usage are dependent on the risks involved in weather events, influenced by multiple factors, including risk exposure, risk perceptions, livelihood stress, and cost-benefit calculations (Martin et al. 2022).

2. Research Approach and Questions

This research follows up on the University of Sussex initiative Forecasting with Fishers that looked at ways to improve the accuracy and value of weather forecasts (Royal Geographical Society 2019). It involved testing localized marine forecasts and co-producing weather information with the local fishers. The new research is framed as an inquiry into early warning early action (EWEA). While there is international research in this field and a wealth of climate and disaster-related research locally, EWEA is hardly addressed in the local context of Thiruvananthapuram. This research attempts to fill this gap.

2.1. Concept of Early Warning Early Action

The International Federation of Red Cross and Red Crescent Societies (IFRC) introduced EWEA as a guiding principle to boost anticipatory action for humanitarian responses, especially with regard to hydro-meteorological hazards (Glantz and Pierce 2023). EWEA became the theme for the 2022 World Meteorology Day. UN Secretary-General Antonio Guterres gave a call to ensure that “every person on Earth is protected by early warning systems within five years” (Glantz and Pierce 2023). EWEA denotes “people-centered, end-to-end, multi-hazard early warning systems” … triggering early action that is well-prepared and tested (UNDRR 2024). As the Red Cross defines, “Early warning and early action, also known as anticipatory action or forecast-based action, means taking steps to protect people before a disaster strikes based on early warning or forecasts. To be effective, it must involve meaningful engagement with at-risk communities” (IFRC 2024).

To act early based on warnings, planners, local communities, forecasters, and humanitarian groups need to understand the impacts of weather-related hazards on people’s lives, livelihoods, and property, and on the economy in general. An effective practice in this field adopted by national and international agencies is impact-based forecasting. It explains what the weather *will do* rather than what the weather *will be* (Anticipation Hub 2024). Impact-based forecasting practices promote comprehensive and credible messages to the last mile so that they contribute to anticipatory action for personal safety and protecting property. Ideally, impact-based forecasting should involve a strong community component of structures, training, and resources that enable early action.

For impact-based early warnings and forecasts to work, it is essential to understand social systems and structures, but such knowledge is “surprisingly weak” (Merz et al. 2020: 36). Considering such gaps of knowledge, this research takes an interdisciplinary approach, combining mixed methods that use weather forecasts, as well as ethnography to overcome the limitations of predominantly quantitative approaches (Hewitt et al. 2017, Hov et al. 2017, Finnis et al. 2019).

EWEA needs partnerships, risk communication, impact information, and training (IFRC 2020, WMO 2021). In this context, the study looks at enabling factors and levels of preventive and real-time action taken by traditional fishers based on marine weather forecasts and early warnings in the event of extreme weather. This combination of forecasts and early warnings is justified in the context of marine weather bordering or reaching extremes on several days of the monsoon season of June–September and during the storm seasons, with early warnings frequently finding a place in daily weather bulletins for fishers.

2.2. Research approach

The research takes into account the interaction of vulnerability, exposure, and hazards in defining risks that are inevitably enmeshed in the socioeconomic contexts of fishers' everyday lives. It acknowledges that people deal with risks creatively and innovatively in line with local cultures and practices (Hewitt 2013a; Montz et al. 2017). Identifying the barriers in using forecasts and early warnings, this study looks at three dimensions of EWEA: i) the contexts of forecast usage at different scales of time and space (Carr et al. 2020), ii) factors that enable and limit the use of forecasts for decision-making and action, and iii) ways in which forecasts are used in line with local and traditional knowledge and cultural practices of the users (Orlove at al. 2004; Findlater et al. 2021).

The research deployed climate ethnography informed by forecasts, observation and weather models as envisaged by Crate and Nuttall (2016) to assess the impact of extreme and uncertain weather on local communities and the fishers' use of early warnings. Climate ethnography traces how climate science relates to the on-ground realities experienced by people and the social and ecological systems and structures around them. It probes how people respond to climate change and extreme weather based on their perception, knowledge, and shared meanings – and adapt. Here, ethnography—involving conversations, interviews, and focus groups—is especially suited to study local climate action by "being there", looking at layers of cultural, social, and livelihood practices, and engaging in daily activities (Roncoli et al. 2009: 87 – 88). As Roncoli et al (2010: 88) argues: "This framing is particularly relevant to the study of climate change, which entails movement away from a known past, through an altered present, and toward an uncertain future, since what is recalled, recognized, or envisaged rests on cultural models and values." These close field interactions can help researchers understand the local relevance and cultural acceptance of the early warnings in line with the fishers' needs and their traditional and local knowledge (Hov et al. 2017; Lemos et al. 2014).

2.3. Research questions

Keeping in mind the above-mentioned theoretical aspects, the research probed the following primary question: *Are last mile communities able to take preventative action based on early warning messages?*

As a corollary, the following sub-questions were addressed:

i. Prevalence and seasonality of hazards that require early action

ii. Inputs for early action (Lentz and Maxwell 2022):

a) Information — needs, quality, and actionability

b) Early action procedures, capacity, financing, triggers, roadmap

iii. Factors that influence early action at the last mile:

a) Risk knowledge

b) Monitoring and warning services

c) Dissemination and communication

d) Response capability and constraints (Basher 2006)

3. Methodology

3.1. Study Sites and Community Profiles

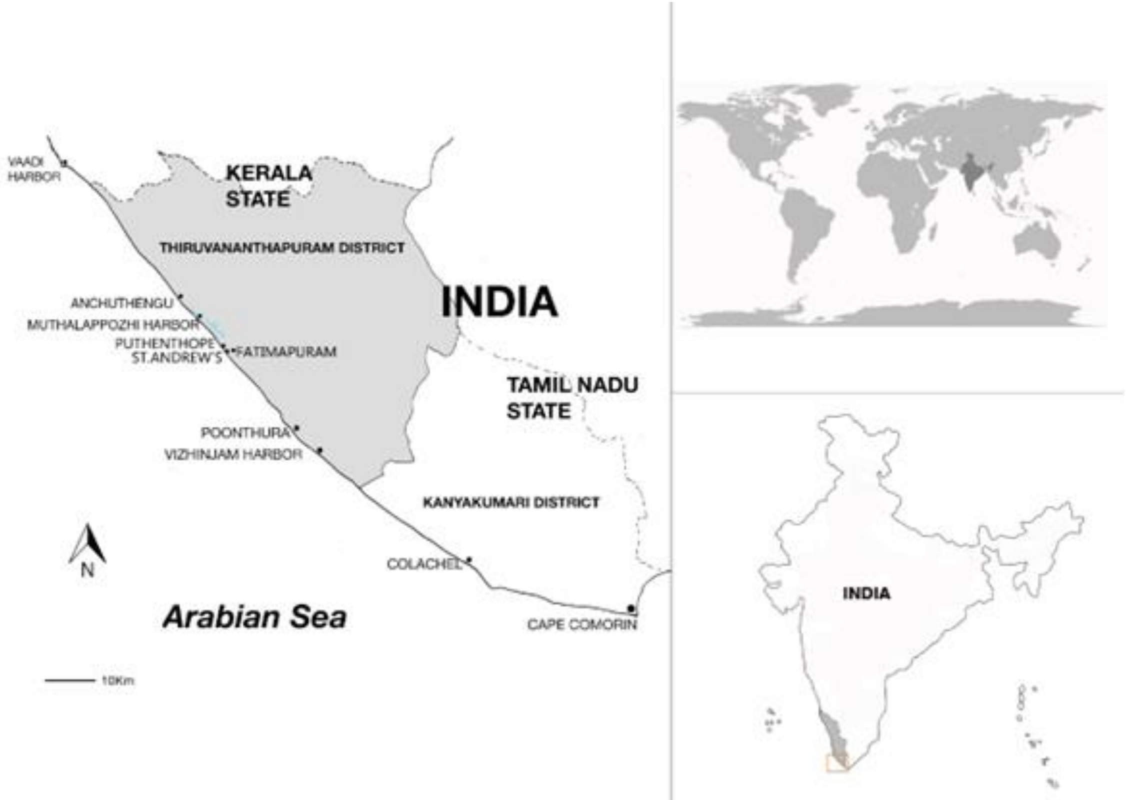

Figure 1: Field study areas in Thiruvananthapuram district, southwestern India. Map by John Bennet

After a detailed literature review and a reconnaissance visit, we selected the field site. It is located in the central-north part of the Thiruvananthapuram district (as shown in Figure 1), where fishers engage in diverse fishing practices — usually very close to the shore but occasionally far offshore. This place is known for its vibrant artisanal fishing scene and attracts fishers from elsewhere due to the presence of fish-rich underwater reefs. The study area comprised five villages spread across 15 km. This place has similar marine wind conditions (Kurup et al. 2023).

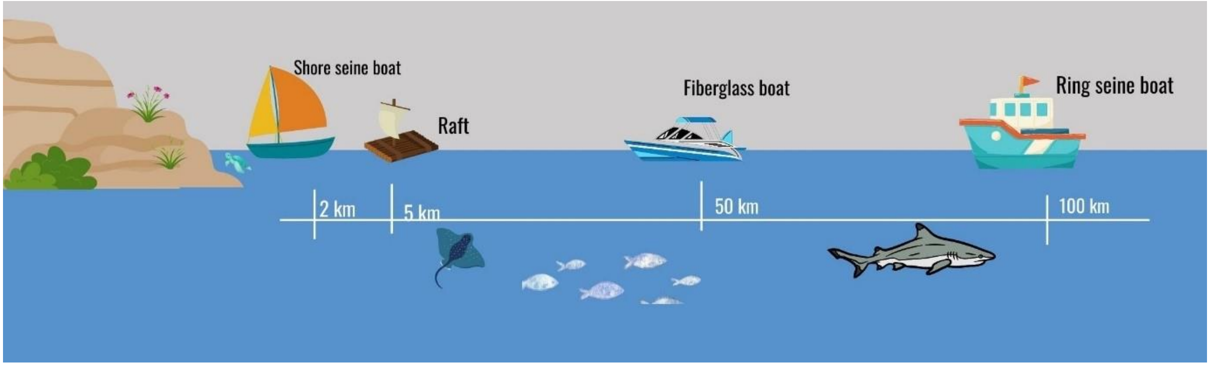

Figure 2: Distance from the shore where traditional craft operate (not to scale). Graphic by Roshni Rajagopal

The fishers here engage in shore seine, hook and line, boat seine, and different kinds of net fishing at different distances from the shore in diverse craft, as shown in Figure 2. These are the villages chosen for the study, from north to center:

a. Anjengo: A large traditional fishing village where fishers use an estuarine harbor called Muthalappozhi that often faces high waves. They often cannot use the local beach as it is eroded and lined with seawalls. The sample here comprises fishers from 10-meter fiberglass boats with twin outboard motors, each one of usually 11 to 40 Horsepower (Hp).

b. Perumathura: The location of the estuarine harbor, Muthalappozhi, has high waves during the monsoon season. We selected a sample of fishermen who work in medium-sized ring seine boats based at the harbor. They come from different local villages.

c. Puthenthope: A village with a minority of fishers. They launch and land their canoes, rafts, and small boats on local sandy beaches. This place is famous for traditional raft fishing, as reefs close to the shore are rich fish habitats. The rafts here are made of four logs, three to six meters in length, chiseled, shaped, bent, and lashed together. We selected raft fishermen who operate in the coastal waters where fish thrive in rocky and sandy reefs.

d. St Andrew's: A village with a minority of fishers. Its wide sandy beaches attract shore seine fishers from different parts of the district where the seashore is eroded. As the number of local fishermen engaged in fishing is limited here, we included respondents from here as well as shore seine units belonging to three nearby villages. Each shore seine unit comprises a surrounding net cast in the shallow coastal waters with the help of a traditional wooden boat and the long ropes on its either end hauled from the shore by 20–50 men.

e. Fatimapuram: A village of migrant fishers from southern Thiruvananthapuram. The fishers here operate their boats on the sandy shores of St Andrew's on the western side of the village across a canal. We selected fishers from 10-meter fiberglass boats with twin outboard motors.

3.2. Research Design and Methods

At first, we held informal conversations and group meetings in each of the study areas. Two research assistants, who are local residents, approached fishers in the village commons spaces where they park boats and mend nets. They were informed about the study, its objectives and anticipated outcomes, and invited to further discussions. Each of these informal meetings lasted about 20–30 minutes. These discussions were about the weather, risks, and safe fishing. Based on these conversations, for each group, we selected a purposive sample of ten fishers willing to engage with the research. The sample in each place was selected on the basis of the fishers' consent and being a member of the crew of the specific craft/fishing. Their local residential status, basic understanding of the local weather, sea state and risk factors, and experience in traditional fishing were the other selection criteria.

The local research assistants were trained in interview methods and in conducting focus group discussions. The principal researcher stayed in the field from November 2023 to February 2024 and participated in interviews and conversations with fishers. The two research assistants continued work till the end of April 2024. A total of 50 interviews were conducted, ten with each of the five groups of fishers – namely, fiberglass boat fishers of Anjengo, raft fishers of Puthenthope, shore seine fishers of St Andrew's and nearby areas, fiberglass boat fishers of Fatimapuram, and ring seine fishers who operated from the harbor at Perumathura. Interviews focused on the hazards the fishers faced, the need, use, and action based on early warning. They covered weather, sea state, risk factors, attitudes to risk, forecast usage, early warnings, action taken on early warnings, and factors that aided and hindered action. Each interview lasted about an hour – in some cases with a follow-up session to clarify and explain some of the finer points discussed. The respondents were asked about their personal experiences and choices as well as group decisions taken in the face of adverse weather. The interviews followed a standard questionnaire, and the responses were recorded digitally and transcribed and translated manually.

Besides, ten key informant/expert interviews gave the research team insights from a disaster management perspective. They comprised two elected panchayat (local self-governance body) leaders, a fishermen's' association board member, a state government official supervising scientific aspects of early warning early action, two priests with long experience working with fishers in the study region, a senior scientist leading research and development activities in a national forecast agency, a community weather news producer, a social worker and an ocean researcher.

We hosted focus group discussions toward the end of the study. They offered the researchers an opportunity to look at how fishers collectively responded to early warnings. These discussions also gave an opportunity to conclude the research and inform fishers of what the researchers observed so far and the next steps involved in the study. All meetings and focus group discussions were facilitated by two local research assistants. They enjoy the fishers' trust and goodwill, and that made the data gathering via embedded networks in the local communities reliable.

The focus group discussions with each of the study groups gave further insights into group decision-making processes and action points. Further, the research assistants routinely met these groups of fishers at their work place and gathered details of their fishing experiences and weather conditions. Sticking to the conventions of ethnographic research, these informal conversations added a personal dimension to the data that the fishers shared in interviews and focus groups.

The standard methods in climate ethnography involve placing ethnographic data in the context of forecasts, observation, and weather models. Therefore, weather forecasts and early warnings were tracked from the comprehensive bulletins issued daily by *Radio Monsoon*, an online and phone-in weather service in the local language, based on official forecasts and background information. Further data on extreme weather events were cross-checked from the websites of IMD and INCOIS and datasets. Besides, data referred from these sources give a general indication of the hazards that fishers face and exposure to weather forecasts and early warnings. Overall, these datasets provided the necessary scientific background for the study.

3.3. Data analysis

All the interviews and focus group discussions were thematically coded and analyzed. Themes such as hazards, risks, perceptions, early warning message and their dissemination, decisions, and early action components captured the narratives shared by different groups of fishers. The work involved the identification of themes through careful reading and re-reading of the transcribed data and tabulation of data and analysis (King 2004). The quantitative part of the data, such as the number of fishers expressing similar viewpoints, was calculated in Excel, along with field notes explaining the rationale behind these decisions. Thematic analysis facilitates identifying, describing, and interpreting patterns within a data set in detail and helps the researcher make sense of complex issues (Braun and Clarke 2006).

4. Findings

4.1. Prevalence and seasonality of hazards that require early action

Wind and waves: The southwestern monsoon season is a dangerous time to fish as the sea becomes rough with high wind (over 40 kmph) and waves (over 1.5 meters) that are risky for small fiberglass boats (30–34 feet) and even smaller canoes and rafts. Ironically, the monsoon season is also marked by good fish catch, prompting fishers to fish irrespective of the weather conditions and inherent risks (Martin et al. 2022). In conversations, the fishers said that they cannot easily know what the wind conditions are offshore. Ocean states can change quickly and dramatically – even along the coast. Sometimes, during the calm season following the monsoon, the sea may look like a calm body of water. Still, there can be sudden waves.

The sea state is influenced not only by the local winds but also by far-away storms and high wind events, changing wind direction and speed, and gusts. The fishers also be careful about shore waves, swells, coastal, surface, and deep currents. A traditional fisherman tackles the waves without any formal training, data backup, standard operating procedures, ground control systems, or even a life jacket. Fishermen said that they know very well the limits of their boats and rafts. During the rainy season, wind, waves, fog, and lightning are among the hazards at sea. Wind is the biggest risk factor for small boat fishers. Boat fishermen on 10-meter fiberglass and bigger ring seine vessels said they do not work when the wind speed is 40kmph. Raft fishermen said they usually return when the wind speed crosses 25 kmph.

Risk exposure: Most of the fishers in the study operated within 50 km of the shore. Among the fiberglass boats, seven out of ten boats tracked in each village usually operated within 50 km. However, they sometimes went as far as 75 km and rarely 100km from the shore. All ten rafts operated within 8 km of the shore. All the shore seine craft operated within 2 km from the shore. Half of the ring seine vessels operated within 50 km most of the time, though occasionally, some of the vessels operated at 200 km distance. During the study period (Oct–March), most of the crafts launched from their home beach. However, during the monsoon, they preferred launching from the harbor at Muthalappozhi, close to Perumathura.

Figure 3: A raft fisherman of Puthenthope village escapes high waves. Still from the documentary 'Crashing Waves', shot by Vincy Lopes

The crew of four fiberglass boats from Anjengo preferred to launch from the Vaadi harbor in the neighboring district of Kollam district (popularly known as the Kollam harbor) about 37 km north; and of two boats occasionally launched from the Kollam harbor. The fishers would take the boat there by trucks, dock it there, and commute by taxi or bus for work. Two of the boats operated from Muthalappozhi during the study period and during the rainy season (unless they went to the Vizhinjam harbor 40 km to the south). Muthalappozhi is known for frequent accidents, especially during the monsoon, due to what the fishers term bad harbor design," which involves a narrow mouth, breakwaters that do not effectively block the waves, and frequent siltation causing high waves within the harbor (Shaji 2023, Martin 2023). One of the fiberglass boat crews of Fatimapuram preferred the Muthalappozhi harbor during all seasons and one Kollam harbor during the rainy season. One of them traveled to Kollam or Vizhinjam.

Eighty percent of the raft fishers we interviewed preferred not to fish during the rainy season when the shore waves are too dangerous for them. The minority who fished during the monsoon operated from the Muthalappozhi harbor. None of the shore seine units we studied worked during the monsoon season. However, a few other shore seine and raft fishers—who were not part of our study group—worked during the monsoon despite the risks, as a new documentary titled 'Crashing Waves' shows (Bennet 2024). The monsoon season of 2023 was marked by high waves, as the documentary depicts. A visual analysis of video footage recorded during the monsoon season shows that frequent shore waves of more than 2 meters pose a high risk to small craft, causing occasional capsizes, including a casualty (Bennet 2024).

The shore seine crew members fishing very close to the shore found that extreme weather events are becoming more frequent. All the respondents shared this opinion. At that same time, seventy percent of the raft fishers and ninety percent of the ring seine fishers, who often go far offshore, also shared this perception. However, most fiberglass boat fishers said they do experience extreme weather from time to time, though not very frequently. Only twenty percent of fiberglass boat fishers from Fatimapuram said extreme weather events were becoming more frequent. From what the fishers shared, it appears that shore waves are gaining strength and posing more risk to fishing.

This apparent trend of high waves appears to affect shore-based and nearshore fishing operations more as the craft used in these operations are constantly exposed to shore waves. Often, these rafts and rope-tied traditional boats are propelled manually by oars, and they lack safety mechanisms such as lifejackets and radio sets. Fishers on these craft depend on their ability to swim back to the shore in the event of a capsize or an accident. Still, the fiberglass boat crew also expressed concerns about safely crossing the wave zone amidst high waves even with powerful outboard motors of 25 or 40 Hp.

The perception of the fishers that the sea is becoming rougher than it used to be appears to have some connection to the recent trend of intensifying storms. As mentioned, scientists confirm that oceans are becoming warmer, and storm activity is increasing. The literature shows that in recent years, the Southern Ocean, South Indian Ocean, and Southern Atlantic Ocean have faced frequent extreme weather events (Gramcianinov et al. 2023). These are the oceans from where swell waves that hit the coasts of southwestern India originate. Over the past four decades, there has been a significant increase in extreme cyclones over the Southern Ocean. During 2009–2022, there has been a seven-fold increase, mostly over the Amundsen and Bellingshausen Sector—an arm of the Southern Ocean— and the South Indian Ocean (Lin et al. 2023), While it is established that these remote events influence seasonal wave action close to the shores of southwestern India, the recent trend that the fishers observe in wave patterns require systematic analyses of long-term datasets. In summary, the fishers are witnessing high wave action, and it appears to correlate with increased storm activity in remote oceans. These aspects require careful observation and analysis.

Figure 4: A shore seine boat negotiates high waves in Thiruvananthapuram. Still from the documentary 'Crashing Waves', shot by Vincy Lopez

Wind: Data from our recent research shows that the most prevalent wind speed in the coastal waters of the study area (within 25 km) during the monsoon season is 20–25 kmph (10.8 to 13.5 knots), occasionally crossing 30 kmph (16.2 knots) (Nirmal et al. 2023). In the Beaufort Scale, this wind speed is categorized as a moderate breeze, and it can generate waves of 1 m height with "occasional white horses", denoting breaking waves (WMO 1998, NWS 2024). Forecasts and observations, however, showed higher wind speeds offshore.

During the monsoon season, there were IMD alerts and warnings for the Kerala coasts on 23 days of June 2023, another 23 days of July, and five days of September with 40-45 kmph wind and 55 kmph gusts. IMD advised fishers not to go to sea on these days. During the field study period of November–April, the wind and waves were not as high or as dangerous as during the monsoon. There were six alerts in October and two each in November and December. In January, there was one alert. There were no high wind alerts in February and March. A typical alert reads like this:

"(Day 1) Squally weather with wind speed 35 kmph to 45 kmph gusting to 55 kmph likely to prevail along and off Kerala coast. Fishermen are advised not to venture into the sea" (IMD 2024).

The respondents from all categories, however, noted waves as the riskiest part of their work, along with high wind. At Anjengo, half of the fiberglass boat fishers listed waves as the highest risk factor, but all of them cited wind as the riskiest factor. At Varkala, most fiberglass boat fishers interviewed (ten out of seven) listed waves as the highest risk, with three respondents noting high wind. Among the raft fishers of

Puthenthope, eight respondents each listed waves and high wind as the riskiest part of their work. Nine shore seine fishers of St Andrew's reported waves as the riskiest component, and all ten recognized high wind also as risky. Significantly, all the ring seine fishers, whose vessels can withstand two-meter waves unlike small craft, also listed waves as the biggest risk.

Summing up, the fishers expressed the concern that shore waves pose significant risks to all forms of fishing. The risk scenarios they mentioned included the waves hurling the boat up in the air and crashing it against the shore, the seabed, or water – this can break the boat and put the crew at serious safety risk. Another risk is that the boat can capsize if it goes at the wrong angle against the waves. The waves can sometimes inundate the boat and sink it.

Swells: Coastal flooding and erosion did not figure prominently as risks in the interviews. However, there was a long-period swell wave event on 31 March, close to the end of the fieldwork. The recent "Kallakkadal" — a local term accepted as scientific to describe long-period swell wave events—had disastrous impacts in parts of the Kanyakumari, Thiruvananthapuram, Kollam, Alappuzha, and Thrissur districts. The March 31 swell event flooded 50 houses in north Kanyakumari. People were evacuated. Two events followed —in early April and later, just after the study period, on May 4 and 5. The swells continued intermittently till early August (when this report was filed). The first event was described as "terrible" in all the focus groups that immediately followed it. It had an unexpected destructive power, the fishers said.

Fig 5. Swells from South Atlantic storm break as giant shore waves in southern Thiruvananthapuram. Photo: Vincy Lopez

Fig 6. Swells pound southern Thiruvananthapuram. Photo: Vincy Lopez

Fig7. Swells from a distant storm destroy houses in southern Thiruvananthapuram. Photo: Vincy Lopez

Fishers at Puthenthope said that they pulled all the craft up the shore with the help of tractors (that are usually used to help fishers park their vessels after landing). At night, the waves flooded the shore and damaged the fishing gear kept there. It was an unexpectedly severe event, as a fisherman from Fatimapuram described: “We keep getting messages about 30–40km wind and three or four-foot (0.9 –1.2 m) waves... We don’t take them very seriously. We did not expect such a serious event. Usually, we can get a sense of the atmosphere and the sea state.” As shore seine fisherman described it: “The sea was calm till the previous day. This was unexpected. There are high wave events almost every year. But this time it was like a dog lying quietly, suddenly jumping out and biting you.”

Storms: The North Indian Ocean had its second-most active storm season on record in 2023, with considerable disturbances over the Arabian Sea. The early season witnessed cyclone Biparjoy developing into a Cyclonic Storm (62—88 kmph wind speed) on June 6. It rapidly intensified twice, aided by Arabian Sea surface temperature of 31 degree C to 32 degree C – that is 2 to 4 degree C above the climatological mean, well above the 27 degree C temperature needed to sustain a tropical cyclone. Biparjoy gained speed from 55 to 139 kmph by 7 June and further intensified between June 9 and 10, sustaining a wind speed of 196 kmph till 11 June, making it an ESCS or a category 3 storm on the Saffir Simpson scale before its landfall over Yemen (NASA 2024a). In the late season, Cyclone Tej became another Category 3 storm with 200 km/h winds on October 22, making it the seventh-strongest tropical cyclone on record in the Arabian Sea. Tej made landfall over the Gujarat state of India. As their tracks were away from the shores of Thiruvananthapuram, they had little impact on the coastal waters here. However, there were fishing restrictions, even when Biparjoy was moving far northwest. Meteorologists said the impact on the coastal waters was negligible.

The fishers clearly see that the storm activity is increasing. Their observation is confirmed by the literature. An increasing storm trend has serious impacts on fishing. First of all, it makes fishing more risk-prone due to the dangerous sea states associated with it. Second, it reduces the number of fishing days available. This has serious livelihood implications. Third, storms can have serious impacts on coastal habitats and infrastructure. Even distant storms are causing frequent episodes of coastal flooding by long-period swell waves. In short, one of the most visible and significant signs of climate change on the southwestern coast of India is the impact.

4.2. Information for early action: needs, quality, and actionability

Information sources: A diverse set of information sources are used for fishing, as our interviews and focus groups show. The most prevalent mode of information is television. As part of the general news and as text scrolls during entertainment programs, weather news frequently appears on television. All the participating fishers belonging to raft and shore seine crews said they primarily used television news as the main source for weather information. Seven members from each group of fiberglass boat fishers and ring seine boats also said television was their primary source. Seven of the fiberglass boat fishers reported that mobile phone services, including software applications, were their key sources of weather information. One of the most popular weather applications is Windy, and some fishers use Accuweather. Eight ring seine boat workers, five shore seine crew members, and two raft fishers also said mobile phone services were their primary weather information source.

There are several weather services available on mobile phones. The State Disaster Management Authority (SDMA) and INCOIS send text alerts on extreme weather and rough sea states. Besides, there are independent services that interpret and explain official forecasts. Fishers often carry a basic mobile phone while going fishing and leave smartphones behind on the shore. Exposure to sea water, spray, and high humidity can spoil their electronics, they said. Mobile phones can access voice and text service for a certain distance from the shore – usually around 15 km. Further offshore, fishers rely on their wireless sets for sharing weather information. In the case of extreme weather events, the police send messages over common radio channels used by the fishermen. Two of the popular mobile phone weather services are the ones run by the Reliance Foundation and *Radio Monsoon.* As a boat fisherman in Anjengo reported: "I had this phone number of Radio Monsoon on my small (basic) phone. Whenever I go into the sea for work, after I go 10 km from the shore, I would call, and if they talk about safe weather, I will go further. If it is more, I will stay near the shore."

Reach of early warning messages: Local authorities and disaster management authorities noted that there is a centralized system for disseminating early warning messages to the last mile. They work through a dedicated wireless network connected to local revenue offices and police stations and directly through mobile phone text and voice messages. Apart from official channels, automated SMS messages are sent to the fishers' mobile phones, and in some cases, calls are made. Mobile phones are ubiquitous on the coasts of Kerala (Sreekumar 2011). The network is reasonably good in coastal villages. Services are usually accessible up to 10–15 km from the shore. It is one of the most reliable forms of communication for fishers.

The reach of the early warnings depends on the medium at hand and the seriousness of the event. Storm warnings and red alerts of swells reach all parts of the fishing villages through multiple channels. While media give repeated news bulletins and text scrolls (on television), official bulletins are read out over loudspeakers at churches, harbors, and on moving vehicles deployed 7by the local self-governance authorities and the police. Yellow alerts and high wind events during the monsoon season do not receive this level of dissemination. However, church and community loudspeakers often relay these messages. Some villagers said such routine dissemination is discontinued in their areas as they became too frequent. Several fishers ignored them or complained about them affecting their day-to-day work. Therefore, this practice of loudspeaker announcements sometimes becomes ad hoc, with some of the villages withdrawing from the system without notice.

Referring to the March 31 swell event, a fisherman in Fatimapuram said he missed the news "I listen to the news, all the news. This time I did not notice anything being said on scrolled (on television)." He added he did not get any phone message. It was an unexpectedly severe event. However, an elected leader of the local Panchayat refuted this. "Some say they didn't receive the warning. No, the alert was indeed sent out. However, it's possible that some individuals may not have seen it," the leader said. Disaster management authorities noted that messages were sent out through the media and through mobile phone alerts. Usually, state authorities identify fishers' mobile phone numbers through documentation at the fisheries offices – early warning messages are disseminated over these numbers. Disaster alerts meant for coastal communities are disseminated over specific regions.

For their part, INCOIS officials said they had issued forecasts about the March 31 event and an orange alert. While yellow alerts require no immediate action, orange ones note that advise people on the coast to be "careful while doing marine operations and nearshore recreation," and red alerts note that "small vessels not to ply, nearshore recreation activities to be totally suspended, and erosion wave surges possible" (IMD 2024). A senior official said: "Warnings were issued, but nobody took them seriously (at first). The public memory is often short, and so is the memory of the system," he official added.

As one of the raft fishers in his early 60s at St Andrew's noted: "Now the sea is calm. Sometimes, when there are rain clouds, we observe the wind and the atmosphere, and sometimes we won't go. Because we do things according to what my father taught me. So, he has told me that this is how things are and that we shouldn't go. So, we won't go." He said he does not listen to weather forecasts. Meanwhile, a fisherman in his early 70s said he took forecasts about wind speeds of 40 kmph or above very seriously. Though it is often not very clear from the shore, once offshore, the fishers feel the impact of the weather. "The sea will look calm like this. When we go into the sea, it will get dark and rainy and there will be wind. When we go, we cannot tell," he said.

Most fishers in the study area showed a certain degree of surprise about the swell event. A boat fisherman in Fatimapuram said he did not expect such a serious swell event on March 31. "Usually, we can get a sense of the atmosphere and the sea state." As a shore seine fisherman described it: "The sea was calm till the previous day. This was unexpected. There are high wave events in the year. But this time it was like a dog lying quietly, suddenly jumping out and biting you." It appears that despite a yellow alert and media news about the swells, fishers took it lightly. One of the possible reasons for this lukewarm response appears to be the high number of wind and wave alerts the fishers receive – even when they perceive no immediate danger.

Reliability of information: Fishers shared concerns about the accuracy and relevance of weather services. Only one fisherman from both the boat units and two shore seine fishers perceived the forecast to be accurate most of the time. Despite their concerns about accuracy, most of the fishers found forecasts useful. Eight boat fishers from Anjengo, six from Fatimapuram, nine raft fishers, six shore seine fishers, and eight ring seine fishers stated that they found the forecast useful. The refrain is that when high wind is forecast, it may happen "somewhere sometime, not necessarily here". The fishers said that advisories that go as part of the daily weather forecasts of IMD are largely generic and often irrelevant to the local coastal waters. The fishers further explained that what they need from forecasts are details – the type of wind, its speed, where it is blowing, and how much impact they can have in their fishing areas. A generic statement about 40 km/ph wind along the coast of Kerala meets the forecast standards in terms of accuracy; however, its value is limited for fishers operating within 10 or 20 km from the shore, where the wind speed is usually much lower.

One of the examples of useful forecasts given is the detailed graphics of wind speed at 25km-by-25km grids tested as part of the Forecasting with Fishers research during 2020 – 2022 (Kurup et al. 2024). They were shared online and over WhatsApp groups run by the *Radio Monsoon* weather service with the local fishers. There have been efforts to produce localized experimental forecasts at 25 km x 25 km grid sizes and share them with fishers, gather feedback, and share the date with national forecasters for potentially wider operations use (see Kurup at al 2024),

The above research underscored the need for more localized forecasts for different parts of the districts with distinct wind characteristics. Southern parts of the district are marked by higher wind speeds in the northern parts, for instance (Kurup et al. 2024). The fishers also sought more timely forecasts – bulleting available every four hours, for instance, and outlook for the following days. Such information is available on the website of the IMD in English but is seldom made available in the local language over popular media, except for some experimental and small-scale initiatives.

Fishers, in general, shared the perception that there is overforecasting. Earlier studies have shown that the often high-wind events are over forecast in Thiruvananthapuram. A fisherman in Fatimapuram stated, for instance, "We keep getting messages about 30–40km wind and three or four-foot (0.9–1.2 meter) waves; we don't take them seriously." The fishers said that often, these messages are based on overforecasting. "We do not know when these events are actually going to happen, so many of us ignore these," said a boat fisherman. "We just cannot sit on the shore for many days." Even those who stay back after such alerts once they see those who have gone to fishing getting a good catch.

At the same time, officials sometimes deploy systems to convey these warning messages more forcefully. On the days and nights of high wind and high waves, especially when there is a cyclone warning locally or anywhere in southwestern India, police officers are deployed at the harbors. One of the boat fishers noted that at the

Muthalappozhi harbor, the police (stationed as part of a rescue team in view of frequent accidents) tell them when the wind or the waves are too high and advise them not to go, and he listens.

Traditional and local knowledge: Complementing the scientific weather forecasts, the fishers draw from their traditional and local knowledge to make decisions on when and where to fish and when to call off a fishing trip. Nine members of the raft and shore seine groups, eight members of the ring seine group, and five members from each of the fiberglass boat crews said they depended on their traditional and local knowledge about weather and the sea state.

Amongst the study groups, it is the raft fishers who usually do not take gadgets on board as their craft are constantly exposed to water. They said they depended mostly on their traditional and local knowledge. Raft fishing needs advanced skill sets and a thorough knowledge of the local waters and marine weather. Rafts are manually operated, and they work close to the wave impact zone. The sheer nature of their work makes raft fishers dependent on traditional and local knowledge.

Fishers use their traditional and local knowledge for all aspects of fishing, they said during conversations. It comprises the skill to spot fish, navigate, and observe and forecast the weather and the sea state. They routinely use this knowledge for safe launching and landing and assessing the seasonal fish catch and planning adequately with appropriate weather. Fishers said the shape, color, density, and movement of clouds indicate wind and rain events. Change of color in the waters could mean advancing wind, and a “pencil line” under a dark cloud indicates strong winds bringing rain, they added. Certain color variations and the presence of birds hovering over an ocean area indicate the presence of fish shoals. Fishers can also identify the presence of certain algae that attract certain kinds of fish through color variations and the smell of the sea. Veteran fishers can find their coordinates and the position of underwater reefs based on the position of stars at night and church spires, hills, and tall buildings on the coast during the day.

Fishers said they calculate wave patterns to assess a safe window to launch and land their boats. Waves often follow a numeric pattern with fixed intervals. As there are waves influenced by wind in different parts of the sea, there are multiple overlapping patterns and random waves. Veteran fishers said that with regular observation, it is possible to discern these patterns on a given day. An elderly raft fisherman said that waves can be unpredictable. Still, the traditional knowledge and skill sets come to his aid if he finds himself in danger while returning. He often jumps off his craft to escape the waves, and sometimes, he gets hit by the waves. “Even when the waves crash, since I have good lung capacity, I can hold on. We can breathe well, so even if a few waves crash on us and push us down, we will come up to the surface soon.”. This rich repository of knowledge also involves the calculation of wave cycles, an understanding of wave formation and impact in a line with the wind direction, and forecasting seasonal wind regimes and their impact on the sea state.

In short, it is a mix of traditional and local knowledge, long experience, keen observation, discussions with peers, skill sets, and a certain boldness—willingness to take risks and act innovatively, confidence in their skills and courage—that work together to fish successfully. "It is boldness that marks us as fishermen," said a fiberglass boat fisherman in his mid-forties. At the same time, many of these fishermen regularly seek forecasts on software apps and news media, and often, younger fishermen do an Internet search before each trip. Particularly popular are apps like Windy. Researchers and national forecasters note that the fishers' traditional and local knowledge has its merits, and it represents experiential knowledge that has evolved over generations. New research aims to complement this knowledge with scientific knowledge.

Information needs: The field research shows that all the participants actively sought information regarding weather conditions and the sea state before going to fish each time. A fisherman in his early 60s who goes to fish within two km from the shore of Puthenthope on his 6 m raft, succinctly shared his information needs: "Aspects like direction of the wind, height of the wave, whether you can go to the sea, you shouldn't go at all, or you should go carefully and such..." He said that making these decisions involves careful calculations: "When there are warnings like that, if at all we are going to fish in the morning, if there are no signs, we will go ahead. That is because we raft fishers are only in the sea (very close to the shore) for 1 to 2 hours. Even if something happens, we will come back very quickly. Sometimes, we cut the fishing net and come back."

A frequent question from fishers who used the Muthalappozhi harbor was about the possibility of forecasting wave heights at specific times so that they could cross the wave impact zone safely. The wave regime close to the harbor is complex and dangerous due to the river flow in the estuary, currents, and eddies, the fishers said. Forecasters noted that such wave patterns are often hard to model. Frequently, fishers try to do these calculations on their own and sometimes miscalculate the risk. INCOIS officials noted that estuary waves are very difficult to model and forecast, and it involves a number of factors unrelated to the ocean state – such as the harbor design, river flow, changes in sediment transport, siltation, and so on.

Fishers said they made multiple calculations, especially while launching and landing their craft. While launching and landing even on a shore that is very familiar, the fishermen have to take note of a number of factors. These factors include the length and breadth of the boat (that determine its stability), the angle of the approach the craft should take, and the power of the engines or the human resources that can be deployed. As for natural factors they need to know the height, direction and strength of the waves coming from behind, the direction and speed of ocean currents at different depths, the presence of river flow and eddies in estuaries, the depth of the water, the contours of the shoreline, the wind and the tide. As a local researcher commented, a traditional fisherman does more complex calculations than an airline pilot does – but without any gadget, ground control, or even a sheet of paper and pencil.

4.3. Early action: procedures, capacity, financing, triggers, roadmap

Early warning procedures: A statutory body under the Disaster Management Act, 2005, the Kerala State Disaster Management Authority (SDMA) is responsible for generating and issuing early warning messages. Its State Emergency Operations Centre closely monitors weather primarily based on IMD forecasts supplemented by data provided by private agencies. IMD provides color-coded alerts regarding rainfall intensity, amount, and expected area to be affected on a district scale. Sea states and tides are monitored by INCOIS. They issue swell and tsunami warnings. IMD Cyclone Warning Centre, Thiruvananthapuram, tracks and alerts people on low-pressure systems that develop in the Arabian Sea and the Bay of Bengal. SDMA has put in place an incident response system (IRS) at the district level with designated officials and protocols to follow for disaster response. Panchayats and village offices share early warnings and implement disaster management measures at the local level.

Institutional capacity: The government has directed panchayats to train emergency response teams for first aid, shelter management, search-rescue-evacuation, and early warning dissemination. These teams are comprised of men and women who work as volunteers. Besides the Kerala Police, the Coast Guard, and the Coastal Police, rescue teams are deployed as part of the state's disaster response. An elected leader of one of the local panchayats noted: "Warnings come from the district collector's office and the fisheries department. We convey warnings through WhatsApp. In severe cases, we seek assistance from the police and use village administration announcements (over loudspeakers)." The leader added that in intense storms, they rely on the state authorities for guidance.

Fishers and officials said that the Arabian Sea is becoming storm-prone of late. An elected panchayat representative said. "(Earlier) it never happened in the Arabian Sea. Nobody predicted it, and nobody believed it would happen here, but (in 2017) Ockhi proved everyone wrong and took many lives. The waves were very rough, and they took the whole land. We evacuated most of the people when the surge came, but the good thing is many of the fishermen shifted their homes from the seashore, so it seemed easy to evacuate them, and we tried to make them understand. We know the fishermen are very bold, so they will not always listen to the warnings."

Financing: State officials said that fishermen are given compensation for days lost due to non-fishing at the rates fixed under the Mahatma Gandhi National Rural Employment Guarantee Act 2005. It is a social welfare measure that aims to guarantee the 'right to work'. A local panchayat leader said: "We used to provide kits (of provisions) earlier, but now we serve (cooked) food to those who are evacuated due to coastal flooding and other hazards. The representative explained that during the COVID-19 lockdown (2020-‘21), fishers received compensation for fishing days lost due to restrictions on people getting together to work. "Yes, they used to receive 2000 rupees per month and 25 kilograms of rice." Earlier this year, the Kerala government allocated Rs 50 crore (USD 6 million) from the Chief Minister’s Distress Relief Fund (CMDRF) as compensation to fishers who have lost working days due to adverse weather. A total of 1,66,756 families were to be provided with Rs 3,000 at the rate of Rs 200 per working day lost (Madhubuti 2023). Fishers, however, find this sum inadequate as it is just about a quarter of daily wages for casual labor — and fishers often earn more on a good day. There is also paperwork involved, Fisher said. Interviews and conversations suggested that the fishers did not see this compensation as a viable alternative to fishing. Unless asked specifically, nobody mentioned this facility. Mostly, fishers in the study group did not know about this or were dismissive of it.

Trigger and roadmap: Panchayat representatives said that early warnings come from government authorities — notably SDMA and the Fisheries Department. The standard operating procedure is drawn up by SDMA and implemented by the district authorities. As part of the disaster risk reduction measures, the state government is implementing a scheme to relocate families living very close to the shore, exposed to coastal flooding and erosion. However, as the coastal areas are densely populated, it is often challenging to find suitable places that are close enough for the fishers, officials said.

That means there are still families that live within 200 –500 meters from the high-tide line. In focus group discussions, fishers revealed that such habitats are risky, but still, people lived in them. Often, the fishers remained in their old habitats due to a lack of adequate alternatives nearby. Coastal villages are densely populated. Thiruvananthapuram district has a population density comparable to some of the major world cities – 1,509 inhabitants per square kilometer, going by the last census (Census of India 2011). That is somewhere between the population density figures for New York (1800) and Chicago (1300) (UN Habitat 2014).

Land is expensive and often hard to find close to the coasts. Fishers said they preferred to live close to the sea because of cultural reasons, the proximity of kin and kind, and it makes fishing trips easier. Many fishers said they would like to observe the sea to make an assessment of the weather and the sea state. Officials and social workers, however, note that it should be possible to keep the coastal commons freely available for fishers and rehabilitate them in safer places. Some of the local citizens groups have initiated a coastal commons initiative aimed at conservation and disaster risk reduction. However, conversations suggest that such measures are still at an early stage.

Panchayat representatives assured that evacuation measures are in place, and they can commandeer vehicles from public and private sector operators for evacuation. In interviews, the respondents also commented that they could move to safe places within minutes in the event of an early warning. Village volunteers are working with Panchayat functionaries and the police in disaster response measures. They receive regular training and undertake mock operations. However, these activities often do not include large-scale participation of local communities. Fishers said they are generally aware of disaster management measures, but their details and operational aspects are largely left to officials and representatives.

As for planning and preparedness, SDMA has produced multi-hazard maps, taking into account climate change impacts and long-term trends. As a spokesperson noted: “The disaster management authority has generated hazard maps of habitats, infrastructure, housing, and farms based on cyclone wind, storm surge, and heavy rainfall impacts along the track starting from its landfall.” SDMA’s hazard maps also show large parts of the study area as highly flood prone. In interviews and focus groups, fishers did not say they were knowledgeable about these maps. However, they recognized the prospects of coastal flooding in their areas and the response mechanisms in place.

Risk knowledge, dissemination: At the last mile, the fishers have a nuanced understanding of the risks they are facing. They keep a close eye on the sea state and changes in the weather. Interviews suggest that all the crew members have the responsibility to observe the weather and the sea state. Almost all the interviewees said that the decision regarding staying safe in the case of inclement weather is a collective responsibility. Often, senior fishermen, locally called *chelalis*, take a lead role in observing and interpreting weather phenomena in line with the fishers and traditional and local knowledge.

Monitoring and warning services: Officially, the monitoring and warning services are handled by government agencies. As mentioned, SDMA is the statutory body with the responsibility of disaster risk reduction. IMD and INCOIS issue extreme weather and sea state alerts and fishers’ advisories along with regular forecasts. When there are cyclones and depression that are likely to affect the local coastal waters, these two agencies issue joint bulletins. Police, Coast Guard, Panchayats, and local churches relay these alerts and advisories. While the police and the Coast Guard use wireless communication, Panchayats send messages over social media and vehicles fitted with loudspeakers.

Churches hold influence among the fishers, as a majority of the fishing villages in Thiruvananthapuram are predominantly Catholic. Most churches have a village-wide narrowcasting system comprising neighborhood loudspeakers. Extreme weather forecasts and advisories are often shared over this network. They are also read out at churches. SDMA officials said they have successfully tested a system to disseminate warning messages to all mobile phones in a particular region in the event of an emergency.

Communication: Dissemination of early warnings, as mentioned in the section on information, is carried out through multiple channels. While most of the fishers get their weather news from television news, they use mobile phones and wireless sets to share it with colleagues with value addition from the information they get from their own sources. They use apps, independent observation, and talk with colleagues, especially veterans, who have traditional and local knowledge.

Fishers operating fiberglass boats said that they have an informal weather information exchange network involving peers. Usually, this network involves mobile phones on the shore and very close to the shore, but VHF radio sets are offshore. Fishermen said they carried radio sets that could help them communicate short distances of 15–20 km. However, they relay the information across the entire district coastline and beyond and far offshore. Fishers regularly share information across boats. While fishing in the deep ocean, sometimes they communicated with bigger boats from elsewhere and ships with more sophisticated communication systems. “They tell us when strong wind is blowing in one part of the sea. Then, fishers relay this information to others, and they can escape and reach the shore or a safer part of the sea before getting caught in the wind,” said fishers in Fatimapuram. Often, fishers get information about wind patterns from the police over the wireless.

Further, on the shore, fishers routinely seek and share weather-related information. Usually, young fishermen adept at information and communication technologies look up weather information and share it with colleagues. Besides, fishermen spend a lot of time on the shore, mending nets, taking care of their craft, playing cards, and just hanging around. This gives them an opportunity to observe the sea state and learn whether it is safe to go fishing or not and discuss it with colleagues.

Response capability and constraints: Fishers belonging to the two groups of fiberglass boats and the ring seine boats said they are capable of taking early action in the case of a sudden weather warning, even while at sea. Usually, early action involves returning. “We would pull the net and come back soon,” said a fisherman in a much-repeated statement. Sometimes, when returning is not a viable option, they assess the wind speed and direction and move the craft away from its track and wait till it is calm to return. Fiberglass fishers get early warning messages over mobile phones and radio sets. Wireless sets are becoming popular in this part of the Thiruvananthapuram district after the 2017 Cyclone Occhi, the fishers said.

Shore seine fishers and raft fishers said they operated close to the shore and avoided risk in the case of inclement weather. “We operate at short distances from the shore, and we can come back whenever we feel the weather is not good,” said an elderly raft fisherman in Puthenthope. All the fishers said they would adhere to early warning advisories in the event of extreme weather. Shore seine fishers, except the ones who go on a boat to cast the net, work on the shore. They get early warnings over mobile phones or by word of mouth. The crew in the traditional boat used in shore seining is usually within a kilometer or two from the shore, and they can be accessed over mobile phones with or without signals from the shore. Fishers often whoop out and wave white scarves and sarongs to signal the boats and rafts about the sea state and the course to take.

In small boats, such decisions are collectively made, and every crew member has a say. The owner cannot usually override the decision of the crew. However, the opinion of experienced fishermen is respected. In the case of larger ring seine boats, it is the captain of the vessel (called *srank*) or the helmsman (*amarakkaran*) who takes a call regarding responding to weather events.

In the case of swell events, the fishers said the forecasts give them time to react, and they are used to moving their craft and gear away from the shore whenever warnings come. “Get we tractors to pull the boats, and we help each other,” said a fisherman in Fatimapuram. The fishermen said their homes were safely away from the reach of high waves and tides. However, as mentioned above, some of the habitats are located very close to the high tide line.

Constraints faced by all categories of fishers include degradation of sandy shores and construction of unsafe beach structures, including harbor breakwaters. The study area from St Andrew’s to Muthalappozhi estuary comprises an uninterrupted 10 km stretch of sandy shores. Fishers launch and land their craft here safely from October to April. Some of the fishers operate their boats here even during May–September, when the monsoon wind makes the sea rough. However, north of the estuary and the harbor at Muthalappozhi, the five km stretch to Anjengo is largely eroded. Seawalls here are unable to protect the coastal habitats from high waves and swell events. Unlike on stable beaches, seawalls along eroding beaches suffer toe scouring and slumping, and sand in front of them disappears. In Thiruvananthapuram and elsewhere on the southwestern coast, the shoreline to the north of breakwaters tends to erode. Breakwaters and other structures that protrude into the coastal waters hamper the natural beach-building process by blocking the seasonal sediment transport along the beach (Noujaz et al. 2014, Thankappan et al. 2017).

Even with sandy shores, launching and landing boats during the monsoon season is risky, with frequent accidents and incidents. The dangers associated with the Muthalappozhi harbor add to the problem. Many fishers go to safer harbors far away, as noted above. The loss of sandy shores, as well as the depletion of coastal catch, undermines traditional fishing practices close to the shore, such as shore seine and raft fishing. That means more people are compelled to go far offshore, risking high winds and waves. As the ocean researcher pointed out, raft fishing is becoming increasingly unviable, and people of his father's generation in their late 50s are compelled to go on boats after long experience in raft fishing.

Constraints faced by the officials include reaching early warnings to the last mile in time and limited compliance with early warning messages. While SDMA puts in place technologies such as land-based wireless networks connecting local offices, often officials on the ground have to ensure that the fishers receive early warning. It becomes especially difficult once the fishers have launched their boats. There are technology barriers. Mobile phones do not work beyond 15 km from the shore, and all the fishers carry wireless sets. Many fishers do not have wireless, and their wireless systems do not have a range beyond 20 km or so. Many fishers go up to 50 km or even more. The fishers' wireless networks are informal systems with no formal links to any fisheries or harbor authorities. All the fishers do not necessarily carry wireless sets. In rough weather, many of these systems stop working. The advantage, however, is that the authorities can access the fishers' common channels, and the fishers can relay information across large distances.

Compliance with early warning advisories is another issue, as officials noted. "Most of the fishers listen, but a minority does not. They take undue risks," said the senior government official dealing with EWEA. The official, however, said the government does not intend to deploy undue force to meet its disaster risk reduction objectives. "Compliance levels are reasonably good in line with international practices – though not matching the levels of some of the leading countries in this regard. Panchayat leaders said better awareness of disaster risk reduction measures can go a long way in ensuring community participation. Fishers, however, said they comply with early warnings when there is a serious threat, however, there are risk-takers amongst them.

Fishers often face the dilemma of choosing between risking rough seas and staying on the shore without fish.

5. Discussion

5.1. Rising Climate Risks and the Limits of Current Forecasting

The above findings bring three aspects of EWEA into sharp focus. First, the Eastern Arabian Sea and the adjoining Kerala coast, which includes the study area in Thiruvananthapuram, are becoming increasingly exposed to weather-related risks. Frequent and intense tropical storms, monsoon winds, and the influence of faraway storms from the Southern Ocean and elsewhere pose hazard risks here. This new trend requires new and more effective ways of reducing the risk faced by coastal communities, especially traditional fishers whose lives and livelihoods are closely connected with the marine environment. That would mean streamlining regular forecasts with EWEA imperatives and long-term disaster risk reduction and climate change adaptation needs.

Second, while adverse weather is a well-recognized risk factor in fishing, forecasts play a key role in reducing these risks (Finnis et al. 2019; Finnis and Reid-Musson 2022). There have been recent efforts to improve weather forecasting and dissemination. However, in the study area, the fishers' use of marine forecasts adherence to EWEA measures are not at optimal levels. This is a cause of concern for disaster management authorities as there are frequent incidents, accidents, and casualties associated with not only extreme marine weather events but also day-to-day fishing operations in risk-prone weather conditions.

Third, there appears to be a gap in the government efforts to promote EWEA and the fishers' willingness to use them optimally and benefit from these measures. This gap, in effect, undermines possibilities to promote resilience, disaster risk reduction, and climate change adaptation. This also offers an opportunity for better EWEA education and participation.

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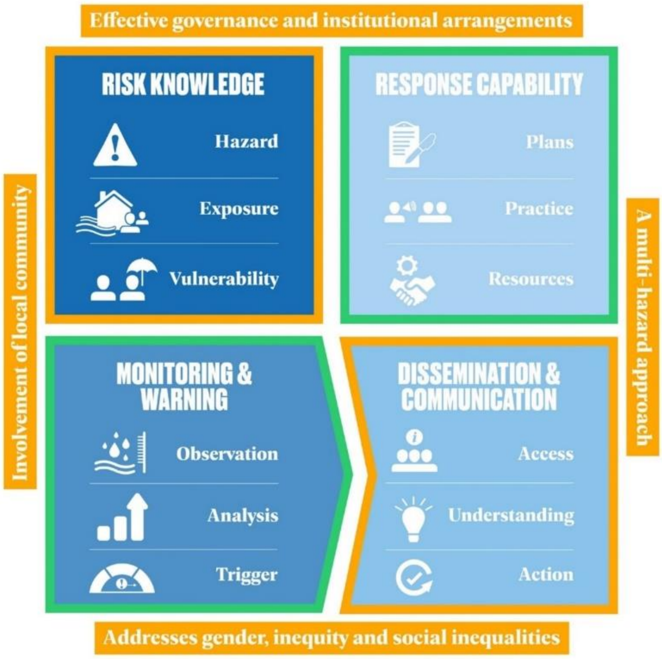

Figure 8. Links between the core components of effective early warning systems and direct (green) and indirect (orange) benefits to resilience Source: Budimir et al., 2023, after UNISDR, 2006

Climate change impacts: The climate change impacts over the Arabian Sea have attracted much academic attention (Murakami et al.. 2017, Panickal et al.. 2022, Nirmal et al.. 2023). IMD has deployed a Cyclone Warning Centre in Thiruvanathapuram. There has been policy action, most notably the setting up of an IMD Cyclone Warning Centre in Thiruvananthapuram. IMD is investing in supercomputers, high-resolution radar systems, and automated weather observatories for better storm forecasts. These investments are expected to improve cyclone detection and more precise forecasts of landfall, wind speed, storm surge, and inundation (Bhardwaj and Ganguli 2023).

Marine weather forecasts, as such, have significantly improved over the past decade. While storms and rough sea states are well-recognized risk factors, fishers bulletins and early warning messages have become more detailed and impact-based over the past two years. They clearly spell out the possible storm, wind, and wave impacts with numbers, charts, and maps. However, the probability and local impacts of these events are often clearly spelled out in the advisories. There is clearly scope for improvement in risk communication leading to early action.

5.2. Disconnect Between Warning Systems and Fishers' Needs

Localized, tailor-made forecasts: Raft fishers, shore seiners, and the crews of fiberglass boats and ring seine vessels have very different information needs. Raft fishers would need to know the weather will be within 5 km from the local shore in the coming 4 hours. Meanwhile, boat fishers would like to know the weather for a distance up to 50 or 75km for a day. Such fine-tuned, nuanced information could be the next improvement in marine weather forecasting. Since routine weather bulletins, especially during the monsoon season, include early warnings, there needs to be a seamless approach in forecasts to make them aligned with early warning action and disaster risk reduction imperatives (Martin et al. 2021).

Localized EWEA: Localized EWEA for coastal areas can help to minimize the impacts of climate hazards by supporting well-planned, locally led early actions before a hazard hits and its impacts are felt. Examples include monsoon rough sea events that lead to frequent incidents and accidents involving small fishing craft and swell events that destroy coastal habitats and flood low-lying parts of villages. As many of these events are seasonal and frequent, there is merit in taking the EWEA aspects into regular marine weather forecasts, along with early warning messages. For instance, a seasonal or sub-seasonal EWEA advisory can potentially prevent hazards such as high wave or swell events from leading to recurrent distress for local communities. It can help break the vicious cycle of recurrent incidents, short-term responses, and recovery from predictable shocks. In the long term, a clearer advisory on long-term storm trends can help avoid future humanitarian disasters (UNDRR, 2022).

Over time, such EWEA can feed into the planning of medium- to longer-term action for climate adaptation and sustainable development needs in general (Martin et al. 2021). Such anticipatory action can also help people avoid maladaptation, such as taking children out of school and selling assets to tide over a rough patch and reduce spin-off impacts such as food insecurity and the possibility of diseases and ill health (CERF 2020, IFRC 2021). Such inadequacies have implications on early action. A generic warning for the Kerala coast would expect every fisher to abandon fishing. That is impractical and unnecessary – unless the weather event involves a storm with wide-ranging impacts. Such blanket warning effectively reduces early action options on the last mile.

There is scope for clearer and more precise communication and information sharing at the community level. Interviews with fishers clearly indicate a dramatic change in coastal hazard patterns marked by the Cyclone of Ockhi of 2017. While seeking forecasts from multiple sources, they demand better, more accurate, and more localized forecasts. responses to extreme weather. This changed attitude to forecasts offers a Window of opportunity to promote better early action based on early warning.

The above inadequacies contribute to the second issue that needs to be addressed. Fishers do not necessarily pay heed to forecasters' advice to stay away from the sea to avoid risk but instead look at more detailed, nuanced, and timely weather information that helps them negotiate risks during the monsoon season. One of the reasons for this lukewarm response to forecasts and advisories is low levels of their perceived local relevance. Forecasts that accurately reflect localized weather impacts are still largely inadequate, as our interactions and earlier analyses of forecasts show. As such, localized impacts mean different things for different groups of fishers. For shore seine crews, it is the wave impact very close to the shore that matters, and for the raft fishers, it is the weather and sea state within a 10 km distance. Fiberglass boat fishers and ring seiners seek details within a radius of 75 km from their point of launching. Occasionally, these boats go beyond and might need offshore marine weather forecasts.

Studies show that early warnings are sent by the forecasters to the user end with options of multiple responses, but the users do not feel they have enough information to make good choices for anticipatory action or even real-time responses (Lentz and Maxwell 2022). Without clear probability information, people tend to guesstimate weather outcomes, sometimes inaccurately. Studies also show that low confidence in warnings, often due to over forecasting and covering more area than what the actual weather event would impact, can influence people's perceptions of weather threats and action (Brown et al. 2023). Another reason for limited trust in forecasts is their perceived inaccuracy, especially the over forecasting of high wind events (Martin et al. 2022). This pattern can be reversed by putting users at the front end or the first mile, planning from known and likely hazards and actions back to information needs (Lots et al. 2012).

As researchers have argued, localized and more relevant forecasts can save lives and reduce livelihood loss due to undue restrictions based on generic forecasts. They can also improve the overall credibility of the forecasts. Of late, scientists have suggested solutions that include better observation, better models, and pooling in expertise of stakeholders and partners from different levels of governance structures and community organizations. The fishers are always looking for details – about the sea and sky conditions of their local shores and at different ocean parts covered by their craft. Primarily, their need is for information to stay safe in an immediate fishing trip. However, advance information helps them plan and summon optimal resources for the following trip.

5.3. Community Engagement and the Case for User-Centered Approaches

Community action: As climate change makes weather events more extreme and uncertain, there is an increasing demand for bespoke weather information for different user groups. This requires combined ocean, land, and atmosphere observations from experts in collaboration with popular science groups, citizen observers, and the users themselves. As an influential commentary put it: "Information must be tailored to reach the right person in the right form at the right time" (Hov et al. 2017: 168). As noted above, different categories of fishers seek information suited to their geographical area of operation and the time spans for their fishing forays.

Community involvement is a key part of early action, as Figure 8 shows. Fishers in all the villages we studied stated that they are aware of the disaster risk they face. However, they are not very clear about the specific disaster response mechanisms, evacuation drills, or the places to go in the case of an emergency. While officials say there are vehicles and buildings at their command, a clear plan listing these resources is not publicly available. A clearer plan that involves community volunteers and readiness to face different challenges—including unexpected and uncertain events—would be necessary in a climate change scenario.

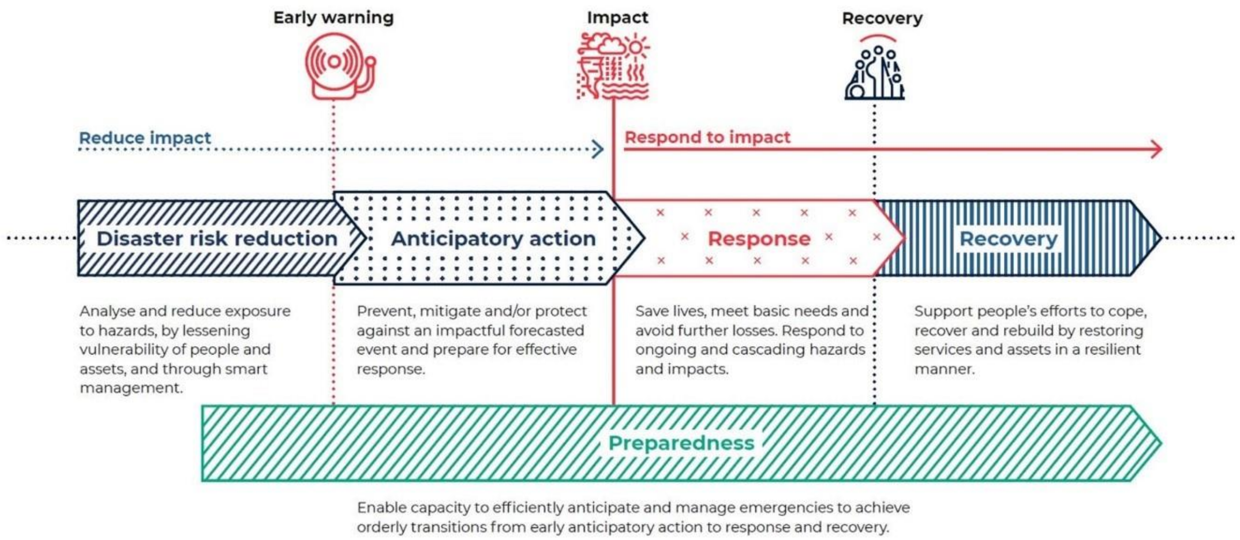

Figure 9: Early warning and early action (labelled as anticipatory action in the figure) can fit into the disaster risk management continuum. Source: (Zurich Flood Alliance 2024)

In a changing climate, frequency, intensity, and the geographical spread of hazards change, and people's vulnerability levels shift in line with development, population growth, and urbanization. These linkages warrant a systemic approach to EWEA. Disaster risk constantly changes, and it is closely connected not only with the risk exposure but also the vulnerability of communities. Studies show that EWEA can fit into the continuum of the overall resilience-building portfolio of communities in line with disaster risk reduction and long-term climate adaptation needs, as shown in Figure 9. While socio-ecological systems can be modified to reduce the hazard risk, mechanisms such as forecast-based financing and insurance can address unavoidable losses. "A coordinated, layered, and overlapping approach between stakeholders, responsibilities, and financing" is what experts call for (Zurich Flood Alliance 2024: 11).

5.4. Implications, Limitations, and Future Research

Study Limitations: This short-term study in a small geographical area, namely a 15km stretch of coast, has some serious limitations in terms of its academic merit and practical applications. It covers only the central north part of Thiruvananthapuram, which is a place with relatively less wind compared to the district's southern parts. The place was chosen for its vibrant reef fishing practices close to the shore, and it offered a vivid account of the risks fishers faced close to the shore. However, the study draws from earlier work that covers the whole district and fishing villages on its southern and northern end that share similar livelihood and cultural practices of fishers (RGS 2024).

The second limitation lies in its timing, that is, time after the rough-sea monsoon season of June to September. The fieldwork that began in November (due to the project cycle limitations) missed the EWEA challenges during the monsoon season. To fill the gap in monsoon experiences, the study included aspects of EWEA during the monsoon period and included data from a local documentary that specifically portrayed the risk taken by different categories of fishers in the study area, especially close to the shore, while crossing the wave impact zone. The study, in effect, complements earlier studies in the region done largely during the monsoon season (Martin et al. 2022, Nirmal et al 2023, Kurup et al. 2024).

While the study design took into account risk factors, it left out much of the economic aspects of risk taking (income levels, costs involved in fishing operations, the cost-benefit analysis of different modes of fishing, etc.), which were beyond the scope of the study. That is the third limitation of the study. In a qualitative study, it is often hard to get financial details. Besides, located largely in an informal economy, reliable economic data on small-scale fishing operations is hard to gather. While fishers gave an indication of the costs involved in fishing trips and the loss due to abandoning a trip, the information was inadequate to come to any reliable conclusion.

Practical implications: This study brings into sharp focus the early warning and early action needs of traditional fishers working close to the shore. The wave impacts and the changing swell patterns are discussed in detail, highlighting the need for better and more actionable wave forecasts and early warnings. It mentions the issue of harbor waves that are hard to forecast but pose risks to fishing operations very frequently. Last but not least, it highlights the importance of traditional and local knowledge in early warning and early action and calls for blending it with scientific knowledge in creative ways.

Future research directions: Future research can be broadly in three directions. First, there is a need for research in understanding the marine weather, sea state, changing trends influenced by local and remote events, and their local impacts. The linkages of changing storm patterns in the Southern Ocean, South Atlantic, and the South Indian Ocean with swells and shore waves on the coasts of southwestern India require urgent research attention. It has serious early-warning, early-action implications. Second, there is scope for research, development, and innovation in designing better forecasts. There can be better ways of co-producing and sharing impact-based, localized, seamless forecasts that are streamlined with broader safety, sustainability, and climate adaptation needs of local communities. Third, there is a pressing need to study how EWEA can be more effective with a deeper involvement of the local communities.

6. Conclusions

The above study has closely looked at the local impacts of changing, uncertain, and extreme weather in southwestern India. Intensifying tropical storms and frequent rough sea events make traditional fishing, one of the riskiest professions in the world, even more risk-prone. This context makes better early warning and early action and their more effective use all the more imperative. Probing how traditional fishers act on early warnings in their work environment, this study in the Thiruvananthapuram district of southwestern India highlights the following aspects:

Better forecasts: First, while information for early action is readily available and disseminated to the last mile, its quality and actionability can be improved in line with the local needs of fishers engaged in diverse fishing activities. Primarily, fishers need better access to localized marine forecasts that are more actionable. Forecasts should tell the fishers the impact of the weather events at their areas of work, the EWEA potential of a weather system at different scales of time and space.

Some of the action points are further supported by the *Forecasting with fishers* research initiative (Martin et al. 2021) as follows:

i. **Improve forecasts**, backed with robust observations, modeling, and analyses. Provide forecasting with better weather information at different lead times—3-4 hours, days, months, sub-seasons and seasons—and probability.

ii. **Link** marine weather and sea state forecasters with diverse groups of forecast users and create a feedback loop to improve forecast accuracy, access, and usability.

iii. **Forecast seamlessly across different spans of time and space** in line with early warning systems and disaster risk reduction interventions in different villages and geographic stretches (such as walled areas, sandy shores, estuaries, and cliffs).

iv. **Streamline forecasts with metrics of EWEA** and disaster risk reduction. Give forecast users different response options, including financing for better preparedness and preventive action. Address timely concerns such as accident prevention, search and rescue needs, and response to coastal flooding due to high waves, swells, and tides – sometimes in combination with other factors such as intense rain.

v. **Co-produce weather information products** with forecast users, taking into account their local needs, traditional knowledge and cultural factors that determine forecast uptake and usage (Martin et al. 2021).

vi. **Promote forecasts streamlined with local safety needs**, climate change adaptation, and sustainability initiatives in synergy with user groups.

Better early warning, early action: Second, there are clearly laid out early action procedures and local capacity to implement them. Still, there are limitations in the financing aspects. The roadmap of early action and its various steps are not always shared or discussed with the communities exposed to risk. There is scope for better and closer community engagement by forecasters and officials involved in disaster risk reduction. In line with new collaborative efforts promoted by the international community, there is ample scope for promoting community-based and community-led EWEA initiatives in Thiruvananthapuram.

Better community involvement: Third, the actionability of early warnings depends on the risk knowledge of the affected communities. While fishers gain risk knowledge from official forecasters, the fisheries department and disaster management authorities complement it with information from private sources (e.g., weather apps) and traditional and local knowledge. The complementary nature of risk knowledge needs to be acknowledged and leveraged for better early action.

Even while strictly following government protocols, especially as mandated in extreme events and disaster situations, it might be helpful to draw from the fishers' traditional and local knowledge as well as experience and observations as value addition to regular forecasts. Such co-production efforts can be very effective in making forecasts more relevant and usable (Lemos et al. 2014, Martin et al. 2022).

Local academic and scientific institutions can serve as boundary organizations, helping people access and share weather knowledge in multiple ways. Further, better and more streamlined and localized dissemination and communication measures can aid early action. Some of the solutions that fishers have tried in different parts of southwestern India include shared wireless channels for weather updates, coastal community radio/streaming stations, and localized marine weather apps that draw from official forecasts with value addition in terms of localized and impact-based forecasts for different categories of fishers, as spelt out above.

Finally, while fishers, in general, are confident about their response capability, there are constraints that hinder effective early action. The local systems are geared towards facing known hazards. In a climate change scenario, EWEA systems need to take into account the dynamic nature of hazards, the new ‘normal’ levels, uncertainties, and extremes. While there are existing resources, systems, and structures that prepare people to face hazards, drawing a clear roadmap for early action requires more work. In short, seamless, streamlined forecasts that take into account disaster risk reduction imperatives at different timescales and closer community engagement are the ways to promote better early warnings and early action.

7. References

Anticipation Hub. (2024). *Impact-based forecasting and anticipatory action*. https://www.anticipation-hub.org/learn/emerging-topics/impact-based-forecasting

Attwood, D. (2018). *Insight report on safety in the fishing industry: A global safety challenge* (Lloyd's Register Foundation Report). https://www.lrfoundation.org.uk/en/publications/insight-report-on-safety-in-the-fishing-industry/

Bailey, M., Hassan, A., & Dhungel, M. (2019). *Nepal FbF feasibility study*. Climate Centre. https://www.anticipation-hub.org/Documents/Feasibility_Study/Nepal_FbF_Feasibility_Study.pdf

Basher, R. (2006). Global early warning systems for natural hazards: Systematic and people-centred. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*, *364*(1845), 2167–2182. https://doi.org/10.1098/rsta.2006.1819

Bhardwaj, M., & Ganguly, S. (2023, June 21). India to spruce up cyclone forecasting with new supercomputers, radars. *Reuters*. https://www.reuters.com/world/india/india-spruce-up-cyclone-forecasting-with-new-supercomputers-radars-2023-06-21/

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, *3*(2), 77–101.

Budimir, M., Heinrich, D., Bachofen, C., Loveday, S., & McQuistan, C. (2023). *The role of early warning early action in minimizing loss and damage*. Zurich Flood Resilience Alliance. https://unfccc.int/sites/default/files/resource/early_warning_early_action_for_minimising_loss_and_damage.pdf

Carr, E., et al. (2019). Identifying climate information services users and their needs in Sub-Saharan Africa: A review and learning agenda. *Climate and Development*, *12*(1), 1–19. https://doi.org/10.1080/17565529.2019.1596061

Census of India. (2011). *Provisional population totals: Kerala*. Government of India.

Copernicus. (2024). *Marine service*. https://marine.copernicus.eu/

Crate, S., & Nutall, M. (2016). *Anthropology and climate change: From actions to transformation*. New York: Routledge.

Daipha, P. (2012). Weathering risk: Uncertainty, weather forecasting, and expertise. *Sociological Compass*, *6*(1), 15–25. https://doi.org/10.1111/j.1751-9020.2011.00437.x

Daipha, P. (2015a). From bricolage to collage: The making of decisions at a weather forecast office. *Sociological Forum*, *30*(4), 787–808. https://doi.org/10.1111/socf.12192

Daipha, P. (2015b). *Masters of uncertainty: Weather forecasters and the quest for ground truth*. University of Chicago Press.

Findlater, K., Webber, S., Kandlikar, M., et al. (2021). Climate services promise better decisions but mainly focus on better data. *Nature Climate Change*, *11*, 731–737. https://doi.org/10.1038/s41558-021-01125-3

Finnis, J., et al. (2019). Marine forecasting and fishing safety: Improving the fit between forecasts and harvester needs. *Journal of Agromedicine*, *24*(4), 324–332. https://doi.org/10.1080/1059924x.2019.1639576

Glantz, M. H., & Pierce, G. (2023). For the record: Second thoughts on early warning, early action (EWEA), EW4All, or EWEA4All? *Atmosphere*, *14*(11), 1631. https://doi.org/10.3390/atmos14111631

Gramcianinov, C. B., Staneva, J., Souza, C. R. G., Linhares, P., Camargo, R. P. L., & Silva Dias, R. P. L. (2023). Recent changes in extreme wave events in the south-western South Atlantic. *State of the Planet*, *1*, OSR7. https://doi.org/10.5194/sp-1-osr7-12-2023

Gupta, G. V. M., V. Sudheesh, K. V. Sudharma, N. Saravanane, V. Dhanya, K. R. Dhanya, G. Lakshmi, M. Sudhakar, and S. W. A. Naqvi (2016), Evolution to decay of upwelling and associated biogeochemistry over the southeastern Arabian Sea shelf, *J. Geophys. Res. Biogeosci.*, 121, 159–175, doi:10.1002/2015JG003163.

India Meteorological Department. (2024, July 21). Wind warning for fishermen of Karnataka, Kerala coast and Lakshadweep for the next four days [Weather bulletin].

Kurup, P. H., Abhilash, S., Mavath, S., Mini, V. K., Alamirew, N., & Martin, M. (2024). Validation of localized coastal wind forecasts for artisan fishers of southwestern India. *Weather*, *79*, 231–234. https://doi.org/10.1002/wea.4554

Hewitt, C. D., Stone, R. C., & Tait, A. B. (2017). Improving the use of climate information in decision-making. *Nature Climate Change*, *7*, 614–616.

Hov, Ø., et al. (2017). Five priorities for weather and climate research. *Nature*, *552*, 168–170. https://doi.org/10.1038/d41586-017-08463-3

International Federation of Red Cross and Red Crescent Societies. (2021). Evaluation of the Flood Early Action Protocol (EAP): Quantitative impact assessment of the 2020 EAP activation. https://www.anticipation-hub.org/download/file-1823

Indian National Centre for Ocean Information Services. (2024, May 5). Swell surge alert to Kerala, South Tamil Nadu, Lakshadweep, Andaman and Nicobar Islands, Karnataka, Goa, Maharashtra, Gujarat, Northern Andhra Pradesh, Odisha and West Bengal [Press release]. https://incois.gov.in/documents/PressRelease_SwellSurgeEvent_May-05-2024.pdf

King, N. (2004). Using templates in the thematic analysis of text. In C. Cassell & G. Symon (Eds.), *Essential guide to qualitative methods in organizational research* (pp. 257–270). Sage.

Kumar, A. J. (2022, November 22). 145 fishermen died at sea in 5 years in Thiruvananthapuram. *The Times of India.* http://timesofindia.indiatimes.com/articleshow/87842439.cms

Kumar, V. S., & Sivakrishnan, K. K. (2023). Ocean surface wave dynamics off the southern tip of Indian mainland. *Dynamics of Atmospheres and Oceans*, *104*, 101411. https://doi.org/10.1016/j.dynatmoce.2023.101411

Lemos, M. C., Kirchhoff, C. J., & Ramprasad, V. (2012). Narrowing the climate information usability gap. *Nature Climate Change*, 2, 789–794. https://doi.org/10.1038/nclimate1614

Lentz, E., & Maxwell, D. G. (n.d.). *Anticipating, mitigating, and responding to crises: How do information problems constrain action?* http://dx.doi.org/10.2139/ssrn.4043459

Lin, P., Zhong, R., Yang, Q., Clem, K. R., & Chen, D. (2023). A record-breaking cyclone over the Southern Ocean in 2022. *Geophysical Research Letters*, 50. https://doi.org/10.1029/2023GL104012

Martin, M., Todd, M., Osella, F., Kniveton, D., Rowhani, P., Taylor, O., & Alcamo, J. (2021). *Forecasting for food producers* (SSRP Policy Brief 7). University of Sussex and Institute of Development Studies (IDS). https://www.sussex.ac.uk/webteam/gateway/file.php?name=ssrp-policy-brief---forecasting-for-food-producers-final-.pdf&site=492

Martin, M., Abhilash, S., Pattathil, V., Harikumar, R., Niyas, N. T., Balakrishnan Nair, T. M., Grover, Y., & Osella, F. (2022). Should I stay or should I go: South Indian artisanal fishers' precarious livelihoods and their engagement with categorical ocean forecasts. *Weather, Climate, and Society*, 14, 113–129. https://doi.org/10.1175/WCAS-D-20-0044.1

Mathrubhumi. (2023, January 21). Loss of working days; Govt to allocate compensation for fishermen families. https://english.mathrubhumi.com/news/kerala/govt-to-allocate-compensation-for-fishermen-families-from-cm-relief-fund-1.8237569

Merz, B., et al. (2020). Impact forecasting to support emergency management of natural hazards. *Review of Geophysics*. https://doi.org/10.1029/2020RG000704

Montz, B., Tobin, G. A., & Hagelman, R. R. III. (2017). *Natural hazards: Explanation and integration*. Guilford Press.

Murakami, H., Vecchi, G. A., & Underwood, S. (2017). Increasing frequency of extremely severe cyclonic storms over the Arabian Sea. *Nature Climate Change*, 7, 885–889. https://doi.org/10.1038/s41558-017-0008-6

Naqvi, S. W. A. (2016). Evolution to decay of upwelling and associated biogeochemistry over the southeastern Arabian Sea shelf. *Journal of Geophysical Research: Biogeosciences*, 121, 159–175. https://doi.org/10.1002/2015JG003163

Hindustan Times. (2018, March 9). *Ockhi was the deadliest storm to hit India's coast after supercyclone of 1999*. https://www.hindustantimes.com/india-news/ockhi-was-the-deadliest-storm-to-hit-india-s-coast-after-supercyclone-of-1999/story-xSPtGAOs3DoifhFfvWfZUM.html

Nirmal, C. S. A., Abhilash, S., Martin, M., et al. (2023). Changes in the thermodynamical profiles of the subsurface ocean and atmosphere induce cyclones to congregate over the Eastern Arabian Sea. *Scientific Reports*, *13*, 15776. https://doi.org/10.1038/s41598-023-42642-9

National Aeronautical and Space Administration. (2024a). *NASA Earth Observatory, Cyclone Biparjoy churns toward India and Pakistan*. https://earthobservatory.nasa.gov/images/151463/cyclone-biparjoy-churns-toward-india-and-pakistan

National Aeronautical and Space Administration. (2024b). *NASA Earth Observatory, Tropical Cyclone Tej*. https://earthobservatory.nasa.gov/images/151980/tropical-cyclone-tej

National Weather Service. (2024). *Beaufort scale: Estimating wind speed and sea state*. National Oceanic and Atmospheric Administration. https://www.weather.gov/pqr/beaufort

Noujas, V., Thomas, K. V., Sheela Nair, L., Hameed, T. S. S., Badarees, K. O., & Ajeesh, N. R. (2014). Management of shoreline morphological changes consequent to breakwater construction. *Indian Journal of Geo-Marine Sciences*, *43*(1), 54–61.

Orlove, B., Broad, K., & Petty, A. (2004). Factors that influence the use of climate forecasts: Evidence from the 1997/98 El Niño event in Peru. *Bulletin of the American Meteorological Society*, *85*, 1735–1743. https://doi.org/10.1175/BAMS-85-11-1735

Panda, S. K., et al. (2022). A study of rapid intensification of tropical cyclone Ockhi using C-band polarimetric radar. *Meteorology and Atmospheric Physics*. https://doi.org/10.1007/s00703-022-00921-6

Panickal, S., et al. (2022). Increasing frequency of extremely severe cyclonic storms in the North Indian Ocean by anthropogenic warming and southwest monsoon weakening. *Geophysical Research Letters*, *49*(1), 1–11. https://doi.org/10.1029/2021GL094650

Remya, P. G., Vishnu, S., Praveen Kumar, B., Balakrishnan Nair, T. M., & Rohith, B. (2016). Teleconnection between the North Indian Ocean high swell events and meteorological conditions over the Southern Indian Ocean. *Journal of Geophysical Research: Oceans*, *121*, 2169–9275. https://doi.org/10.1002/2016JC011723

Roxy, M. K., Kapoor, R., Terray, P., & Masson, S. (2014). The curious case of Indian Ocean warming. *Journal of Climate*, *27*, 8501–8509. http://dx.doi.org/10.1175/JCLI-D-14-00471.s1

Royal Geographical Society (with IBG). (2021). *Improving safety and sustainability in food production by co-producing weather forecasts*. https://www.rgs.org/impact/fishingforecasts

South Indian Federation of Fishermen Societies. (2017). *Sea safety incidents on the lower south west coast of India*. SIFFS Document.

Shaji, K. A. (2023, July 12). Blood-thirsty Muthalapozhi in Kerala gobbles up lives as fishermen keep sailing into the 'mouth of death'. *The South First*. https://thesouthfirst.com/kerala/on-muthalapozhi-the-mouth-of-death-for-fish-workers-far-south-on-kerala-coast/

Sreekumar, T. T. (2011). Mobile phones and the cultural ecology of fishing in Kerala, India. *The Information Society*, *27*(3), 172–180. https://doi.org/10.1080/01972243.2011.566756

Roncoli, C., Ingram, K., Kirshen, P., Sanon, M., Jost, C., & Hoogenboom, G. (2009). From accessing to assessing forecasts: An end-to-end study of participatory climate forecast dissemination in Burkina Faso (West Africa). *Climatic Change*, *92*, 433–460. https://doi.org/10.1007/s10584-008-9445-6

Roncoli, C., Crane, T., & Orlove, B. (2010). Fielding climate change in cultural anthropology. In S. A. Crate & M. Nuttall (Eds.), *Anthropology and climate change: From encounters to actions*. Routledge.

https://www.researchgate.net/publication/254842629_Fielding_Climate_Change_in_Cultural_Anthropology

Shanas, P. R., Sanil Kumar, V., Sivakrishnan, K. K., Mandal, S., & Yuvaraj, S. (2024). Impact of local and remote winds on the surface waves in the coastal waters of eastern Arabian Sea. *Ocean Engineering*, *295*, 116714. https://doi.org/10.1016/j.oceaneng.2024.116714

Thankappan, N., Varangalil, N., & Kachapally Varghese, T. (2018). Coastal morphology and beach stability along Thiruvananthapuram, south-west coast of India. *Natural Hazards*, *90*, 1177–1199. https://doi.org/10.1007/s11069-017-3090-1

The International Federation of Red Cross and Red Crescent Societies. (2024). *Early warning, early action*. https://www.ifrc.org/our-work/disasters-climate-and-crises/climate-smart-disaster-risk-reduction/early-warning-early

United Nations Office for Disaster Risk Reduction (UNDRR). (2022). *Global status of multi-hazard early warning systems: Target G*. UNDRR, WMO, UNDRR Bonn Office. https://iddrr.undrr.org/publication/global-status-multi-hazard-early-warning-systems-target-g

UN-Habitat Urban Global Observatory. (2014). *Population density by city 2014*. https://ourworldindata.org/grapher/population-density-by-city

United Nations International Strategy for Disaster Reduction (UNISDR). (2006). *Developing early warning systems: A checklist*. Third International Conference on Early Warning (EWC III), 27–29 March 2006, Bonn, Germany. https://www.unisdr.org/2006/ppew/info-resources/ewc3/checklist/English.pdf

World Meteorological Organization (WMO). (1998). *Guide to wave analysis and forecasting* (2nd ed., WMO/TD-702). https://doi.org/10.25607/OBP-1523

8. Appendix

8.1. Interview Questionnaire: Traditional Fishers

Profile

1. The village:
2. Reference number (assigned by the researcher)
3. Age:
4. What type of craft, length, width, and ownership:
5. Experience as a traditional fisherman: Years in different boats and different types of fishing
6. Most frequently travelled distance from the coast:
7. How far do you go in the sea, the direction/ how often
8. Where do you launch and land the boat during October–May?
9. Where do you launch and land the boat during June–September?
10. Briefly tell us about your family members.

Risk knowledge

11. What are the dangers you face in rough weather at sea (wind, waves, etc.)? Near the beach? Offshore?
12. What are the dangers you face in rough weather on the coast? (a) Wind b) Waves c) Tides d) Coastal erosion?

Extreme weather events

13. Identify extreme weather events on the Beaufort scale (explain with a graphic)?
14. Extreme events (wind and sea)
15. How common are such incidents?
    - Which is the safest part of the sea? Which is the most dangerous place?

Surveillance and warning

16. Who regularly monitors the weather/sea conditions?
17. Who informs you about weather/sea conditions and issues early warning in extreme weather events?

Availability of early warning messages/distribution

18. How many times do you receive early warning messages each season (the interviewer explains what early warnings are)
19. How do you listen to/see advance warnings - sources?

Information contained in early warning messages

20. What information do early warning messages provide? Wind speed, direction, waves, height....

Quality of early warning messages

21. How accurate are such warning messages?
22. How relevant are such messages to your work?
23. How useful is the aforementioned information?
24. When you receive a warning message:
    a) >24 hours before the scheduled time of launch
        - 6 hours...
    b) 1-6 hours
    c) < 1 hour
    d) When there are frequent warnings (> 2 days)
    e) When you receive these warnings during fishing (different distances at 0 - 50 nm)

The first action after the warning

25. Who makes the main decision? (To go, where to go, and when)
26. Who implements these important decisions? (At sea, on land...)
27. What life-saving precautions do you take for these situations? Boy, life jacket...
28. What other precautions do you have for these situations — wireless, land-to-land messaging, rescue systems...

Capacity/Responsiveness

29. How much capacity do you have to carry out early action (in terms of knowledge, decision-making power, implementation facilities, resources, and technologies)?

Finance

30. What is the cost of the aforesaid activities (loss of fishing, insurance you get, compensation from the government, and the possibility of getting involved in other jobs)?
31. How can you ensure that early action is financially viable?

Trigger

32. What motivates early action? Fear of life, worry about family, whether you can get money, don't have to pay interest.

Roadmap

33. How do you design, plan, and implement these steps in early action? One by one…

Community Interface

34. Who participates in early action planning (women/children/public servants/panchayats/churches)
35. To what extent do community organizations help/not help early action?
36. What is the role of the police, coast guard, fisheries, and disaster management authority?

Do you have anything to add?

Thanks

8.2. Interview Questionnaire: Key Informants and Officials

Name: **Designation:**

Office: **Contact:**

------------------------------ *remove before transcription* ---------------------------------

Ref no:

Prevalence of extreme weather events

1. How do you define an extreme weather event (that requires action)?
2. Prevalence of extreme weather events (during monsoon/ otherwise)

Monitoring and warning

3. Who monitors the weather/sea state on a regular basis?
4. Who monitors weather/sea state in the event of extreme weather events?

Availability of early warning messages/dissemination

5. How frequently do you issue early warning messages in each season?
6. How do you disseminate early warnings – means of communication?
7. What information do early warning messages provide?

Use of early warning messages

8. What are the steps you take when asked to issue an early warning message?
9. How well do fishers listen to and act on these warning messages?

Early action

10. What are the early action measures you take with reference to early warning?
11. Who makes key decisions on these actions?
12. What are the advantages/disadvantages of taking action? Capacity/response capability

Financing

13. What is the financial implication of the above actions (compensating for loss of catch, insurance, other compensation from the government)?
14. How can you ensure that early action is financially viable for fishers?

Trigger/ Roadmap

15. What triggers early action?
16. What are the different steps involved in early action?
17. How do you plan and implement these steps?
18. What are the challenges?

Community interface

19. To what extent do community organizations help/hinder early action?
20. To what extent do cultural factors help/hinder early action
21. To what level do men and women take part in different aspects of early action?

Conclusion

22. Do you have anything more to add? *Thank you very much for your time and insights.*

8.3. Focus Group Discussion Guide: Traditional Fishers

Venue, time, Facilitators:

Group composition/ type of fishing:

Names, age, Years of experience, contact:

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Ref. No:

1. What kind of fishing are you engaged in?
2. Where exactly do you live – how far from the sea? (Each participant answers)
3. How frequently do you face extreme weather during monsoon/ otherwise?
4. Suppose there is a warning two hours before you go to fish – 40 km wind, 3-meter waves. How would you react? *Step by step. Action by each member of the crew/ owner*
5. Suppose there is a warning while you are 20km offshore – 40 km wind, 3-meter waves. How would you react? *Step by step. Action by each member of the crew/ owner*

This will be followed by a discussion about the risks the fishers faced during the season, early warnings, and early action responses