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# Influence of Climate-Adaptive Technologies on the Life and Livelihood of Fisherfolk Communities in and around the Southern Coast of Bangladesh

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**Abstract:** In recent decades, global society has grown increasingly concerned about climate change because of its profound impacts on humanity, particularly on fishing communities that depend on the hazardous seas for their livelihoods. This research analyzes the technologies used by fishermen and examines their role in promoting sustainability. Specifically, the study investigates how climate-resilient technologies help fishermen mitigate risks encountered during maritime activities. A total of 385 fishermen were selected from the fisheries ghat area of Cox's Bazar using purposive sampling. Data were collected in March and April 2025 through a semi-structured questionnaire administered via mobile devices using the Kobo Toolbox Open Data Kit (ODK) platform. The findings reveal that although a considerable number of fishers use climate-resilient technologies, their adoption is limited by illiteracy, inadequate access to technology, and difficulties in applying such technologies to fishing activities. Nevertheless, the results also demonstrate that modern technologies positively transform fishermen's livelihoods and help them avoid climate-induced threats at sea. This study provides valuable insights for governments and policymakers on integrating technology in fishing practices and the challenges faced by fishermen. It thereby contributes to the development of effective policies to improve the livelihoods of fishing communities in Bangladesh and abroad.

**Keywords:** Climate Change; Fishing Communities; Climate-Resilient Technology; Natural Hazards; Fishermen's Livelihoods; Government and Policy Makers

## 1. Introduction

In recent decades, global climate change has emerged as a significant issue for the international community because of its impact on human existence [1–3]. Climate change significantly affects the fishing community due to the inherent vulnerability of marine operations. The fisheries sector in Bangladesh has a profound impact on economic development and effectively addresses unemployment , especially in rural regions [4]. Despite their significant contribution to the economy and social welfare, fishermen face multifaceted challenges exacerbated by their dependence on favorable weather conditions.

Numerous local and international studies have emphasised these consequences for Bangladesh, which include increasing temperatures, rising sea levels, unpredictable rainfall, more frequent thunderstorms, and strong winds

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and waves [5–8]. These alterations trigger catastrophic events that significantly devastate the assets and socioeconomic conditions of fishermen in coastal regions [9,10].

Fishing is a profession that requires fishermen to be knowledgeable about fishing locations, meteorological conditions, market prices of fish, and seawater quality before embarking on an expedition. The fisheries sector is susceptible to natural hazards such as typhoons and adverse sea conditions [10,11]. Traditional fishermen acquire this information through experience, while others obtain it from various sources, including radio, television, acquaintances, and boat owners. However, fishermen frequently encounter obstacles in accessing this information, which can lead to dangerous circumstances at sea. This barrier to information and communication technology (ICT)significantly affects their livelihoods [12].

Some research has suggested that ICTs may be utilised to enhance climate change resilience and mitigate weather-related risks. Other studies have indicated that ICTs can monitor and reduce the risks of climatic events such as cyclones, tidal surges, floods, and tsunamis [13] through various tools, including mobile phones, radio, television, and social media, by disseminating early warnings and weather advisory services.

The Communication of Risk information within vulnerable populations is a critical area of study. All studies in the current literature demonstrate that ICTs are highly beneficial for fishing activities, particularly at sea l. Nonetheless, the mechanisms behind this utility area not fully elucidated; various explanations exist regarding fishermen's perceptions without a clear consensus. Furthermore, studies on ICTs primarily concentrate on their technical specifications and availability rather than their integration into the socio-economic processes of maritime fishing livelihoods [14,15].

Climate-resilient technology, which includes tools like meteorological updates for deep-sea fishing, represents a novel advancement. This technology is crucial for fishermen to protect their lives from climatic threats and to enhance their profitability. However, only a limited number of studies on this specific technology have been identified in the literature. This study aims to address this research gap by examining the significance of climate-resilient technology for the fishing community in Bangladesh. ICT equipment, including GPS, sonar, computers, the internet, and mobile phones, has been shown to positively influences fishing operations [16,17].

Several factors are critical in determining the adoption of adaptation strategies, including fishermen's knowledge of climate change and their perception of its risks and impacts [18]. Socioeconomic and occupational variables such as income, education level, fishing technology, vessel type, and fishing grounds are also significant [19]. A Sufficient understanding of climate change is a prerequisite for effective adaptation and global sustainability; however, such awareness is often lacking among farmers and fishermen in rural areas [20]. This underscores the importance of citizen participation through education, awareness campaigns, and inclusive mitigation actions to foster positive attitudes toward adaptation [21]. These elements are essential catalysts for improving the socioeconomic status of vulnerable groups, including fisherfolk.

This is particularly relevant for the southern coast of Bangladesh, a region highly vulnerable to climate change impacts such as rising sea levels, intensified cyclones, and shifting fish stocks. In response, the promotion of climate-adaptive technologies (CATs)-including early warning systems, solar-powered cold storage, and GPS-based fish finders-has emerged as a key strategy to enhance community resilience and livelihoods.

Despite the emphasis. a comprehensive understanding of their overall impacts remains elusive. Existing literature predominantly focuses on CAT adoption rates, paying limited attention to the causal pathways through which these technologies affect broader outcomes such as income stability, safety, and community resilience. Moreover, most studies treat CATs as isolated interventions, overlooking their interaction with local ecological conditions, social structures, and governance systems. Consequently, integrated frameworks that combine technological and socio-cultural dimensions of adaptation are underdeveloped, especially within Bangladesh's unique coastal context. A further significant gap lies in understanding the psychosocial effects of these technologies, including how they alter fisherfolk's risk perception and sense of security.

A review of literature reveals several critical evidence gaps regarding the impacts of Climate-Adaptive Technologies (CATs) on fisherfolk. Firstly, there is a scarcity of longitudinal data, as most studies rely on cross-sectional surveys that cannot assess long-term effects or temporal dynamics. Consequently, there is little empirical evidence that directly links CAT usage to measurable livelihood outcomes, such as income stability, asset accumulation, or sustained improvements in fishing efficiency.

Secondly, existing research often overlooks critical contextual variables. There is a failure to account for spatial and regional heterogeneity in in climate vulnerability and technology access. For instance, the experience of fisherfolk in Cox's Bazar likely differ significantly from western part of Bangladesh due to variations in environmental hazards and local infrastructure. Furthermore, a pronounced gender data gap exists; studies largely lack gender-disaggregated data, offering limited insight into how women and other marginalized groups within fishing households experience and benefit from these technologies.

A third major gap is the policy-institutional disconnect. While national frameworks like the Blue Economy Strategy and the Delta Plan 2100 emphasize climate resilience, their alignment with the on-the-ground needs and capacities of coastal communities remains unclear. Research often neglects the critical role of local governance structures-such as co-management bodies and fisherfolk cooperatives-in facilitating or hindering the success of CATs. Similarly, financial barriers, including a lack of affordable credit, subsidies, and insurance, are known to hinder adoption, yet studies systematically linking these constraints to the technological adoption process remain sparse.

Finally, methodologies limitations constrain the robustness of existing findings. The field is dominated by descriptive statistics and qualitative case studies, with a notable absence of rigorous causal analysis. Few studies employ longitudinal designs or quasi-experimental methods (e.g., Difference-in-Differences, Propensity Score Matching) to isolate the true impact of CATs. There is also limited integration of geospatial data, which could reveal how CATs interact with local environmental factors like proximity to cyclone zones or market access. Moreover, potential spillover effects—where technology adoption by some community members influences outcomes for non-users or neighboring communities-are almost entirely unexamined.

By addressing these research gaps, this study aims to investigate the adoption and impact of climate-resilient information and communication technologies (ICTs) on risk mitigation and livelihood sustainability among Bangladeshi fisherfolk. Specifically, it seeks to identify the types of ICTs utilized and analyze their role in enhancing safety and operational efficiency in the context of climate change.

The primary contribution of this research is to provide an evidence-based understanding of fisherfolk's perceptions and adoption behaviors. This understanding is critical for formulating effective fisheries policies that are grounded in local authorities. Ultimately, the findings will aid policy makers and government bodies in promoting the implementation of climate-smart fisheries by clarifying the factors that enable or hinder the successful use of these vital technologies.

## 2. Literature Review

Climate change intensifies risks in maritime fishing by increasing the frequency and severity of strong winds, irregular rainfall, turbulent seas, and thunderstorms. Small-scale fishermen, who often rely on traditional vessels and basic communication tools like mobile phones, are particularly vulnerable to these extreme events [22]. Such events-including cyclones, floods, and rough seas-directly disrupt fishing operations, leading to less time at sea, reduced catches, and consequently diminished income [23].

Beyond lost income, extreme weather damages both productive and non-productive properties assets. Productive assets like fishing vessels, nets, engines, and GPS devices are often impaired or destroyed. This threat also extends to non-productive properties, including homes and infrastructure. A significant proportion of Bangladeshi fishermen live in coastal homes constructed from wood or mixed materials, which are highly susceptible to being partially or completely demolished during catastrophic events, resulting in severe hardship [24]. Furthermore, critical infrastructures such as jetties and landing sites are also threatened by climatic extremes, compounding the losses by fishing communities [25].

An urgent need exists for a comprehensive fisheries management plan in Vietnam to curb illegal fishing and ensure the sustainable use of coastal and marine resources. Such a plan requires effective mechanisms to enhance the capacity of local governments, enabling them to better support community- level adaptation. A study of small-scale fishing households in Central Vietnam, utilizing mixed methods, explored how they adapt to climate change. It found that households employ livelihood diversification both within and outside the fisheries sector, a strategy influenced by factors such as education, labor force, and fishing equipment. Despite the critical importance of protecting coastal ecosystems, the study revealed that local governments currently play a limited role in facilitating these adaptation efforts [26].

A study in Ilaje Local Government area, Ondo State, Nigeria, assessed the livelihood vulnerability of fisherfolk impacted by climate-induced changes in fish stocks [27]. Using a multi-stage sampling technique to surveying 200 respondents, the researchers employed a composite index and the LVI-IPCC framework for analysis. The results revealed that both coastal and freshwater fishing communities face significant vulnerability, with coastal communities exhibiting a slightly higher slightly higher index (0.357). However, freshwater fisherfolk demonstrated more effective adaptation strategies, such as clearing drainages, diversifying livelihoods, and having superior access to farmland and healthcare. While coastal fisherfolk benefited from greater economic access to essential resources, the study concludes that enhancing credit facilities and social services is crucial for improving resilience in both community types [27].

Human-induced greenhouse gas emissions are warming the oceans, disrupting marine ecosystems and coastal livelihoods. Fishers' adaptation progresses from "remaining" to "coping," "adapting," and "transforming," influenced by environmental, social, and economic factors such as access to technology and finances. In Semarang, Central Java, rising sea levels cause tidal floods that increase by about 1 m every decade, forcing fishermen to renovate homes and seek alternative incomes. Many have shifted from fishing to green mussel cultivation, using inundated areas productively. This livelihood transformation enhances income, promotes sustainability, and highlights the importance of transformational adaptation for resilient coastal communities [28,29].

The fishing communities of the Indian Sundarbans, whose lives and livelihoods are heavily dependent on nature, are confronting significant challenges from climate change. To sustain their livelihoods, they have adopted various technologies. This study employed a purposive sampling survey of 150 fishing households, supplemented by secondary data on climate events and participatory methods. The analysis identifies storms and cyclones as the primary drivers of climate exposure. Findings indicate that the coastal villages are densely populated, suffer from limited resources, and have few alternative livelihood options beyond fishing, such as agriculture. These conditions heighten the communities' sensitivity to climate impacts and reduce their adaptive capacity, resulting in a high overall vulnerability [30].

To enhance productivity, Fishermen require access to information on innovative technologies, market conditions, and weather updates. A systematic literature review analyzing blockchain applications in fisheries identifies its significant potential to address these needs [31]. The technology's immutable ledger and real-time data sharing can ensure seafood traceability, verify product origins, and promote compliance with sustainability standards. Furthermore, by reducing intermediaries, blockchain can lower transaction costs and boost fishermen's profits.

The fishing industry is a major employer and a leading sector in Tanzania's Blue Economy. However, its potential is constrained by small-scale practices, inadequate facilities, and limited technological adoption, which collectively limit productivity and efficacy. To address these challenges, this study proposes an Internet of Things (IoT)-based fishing gear. This system is design to automatically count and record catches, display data via mobile application, and send alerts when a target is reached. It also provides navigation support to help fishers locate deployed gears. Results confirm that the system effectively transmits gear location and real-time catch updates, demonstrating that ICT integration can optimize operations, conserve resources, and significantly improve productivity within the Tanzanian fisheries sector [32].

Key applications of technology in fishing operations include vessel tracking for safety and compliance, machine learning models for predicting sea temperature and sea-level changes, and AI-based aquaculture systems for evaluating fish biomass and water quality. Furthermore, AI supports ecosystem health monitoring, biodiversity protection, and pollution management, thereby strengthening conservation strategies [33].

A strong correlation exists between the use of radio and productivity in fish farming. One study demonstrated that increased exposure to technical knowledge via radio is correlated with enhanced productivity among farmers. A similar outcome was observed regarding mobile phone usage within fishing communities [32,33], increased communication and information exchange about fish farming technology through mobile phones also correlates with higher productivity [33,34]. Furthermore, partial adoption of modern innovations in fishing vessels and equipment has enhanced traditional techniques and significantly increased production within these communities [35].

## 3. Methodology

This study employs a quantitative research approach. Data were collected from the fishery community in the Cox's Bazar Fish Harbour area, located within Cox's Bazar Municipality on the southern coast of Bangladesh (**Figure 1**). This site, situated along the Bakkhali River, functions as the primary wholesale fish market in the region.

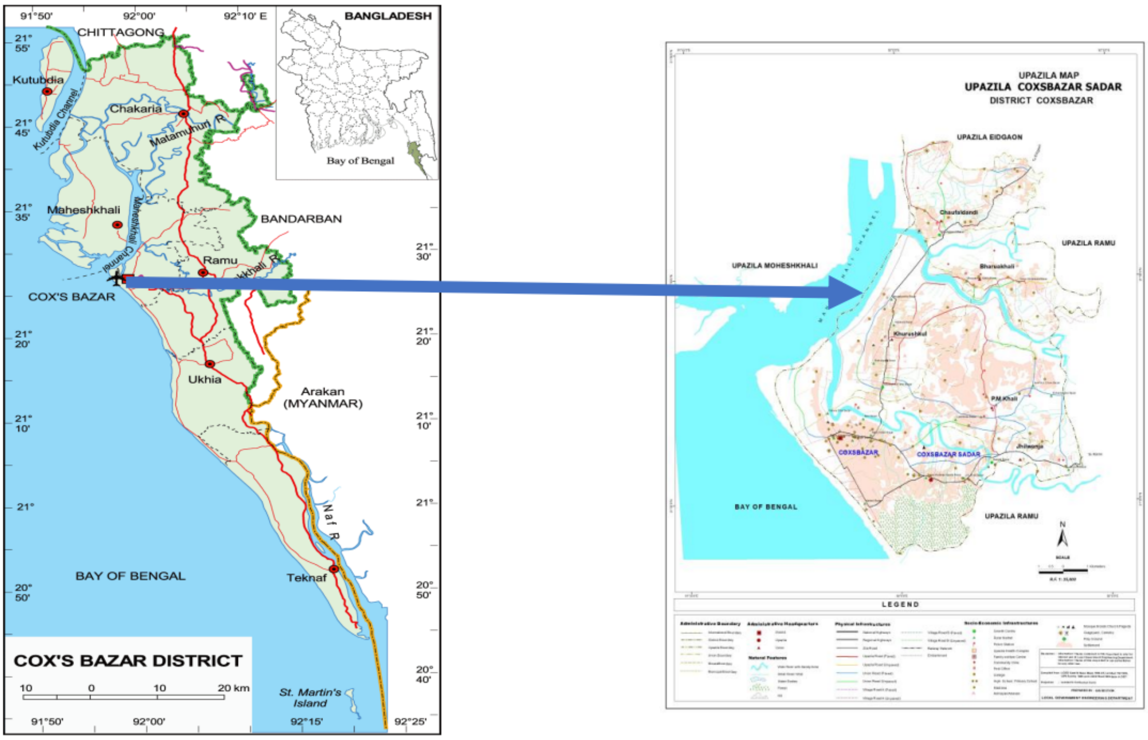


**Figure 1.** Geographical Location of the Study Area.

This study area, located near the Bay of Bengal, is highly vulnerable to climatic hazards such as cyclones, tidal surges, coastal erosions, and floods Consequently, fishermen in this region must maintain constant vigilance to mitigate risks at sea. Data were collected in March and April 2025 using a semi-structured questionnaire administered via mobile devices. A purposive sampling method was employed, selecting 385 fishermen for interviews. To avoid duplication, the study prioritized interviewing the head of the each fishing households.

These sample sizes were selected with the help of the statistical representative formula [35], such as

$$Formula, n_0 = (\frac{z^2pq}{d^2})$$

Where $n_0$ = desire sample size, $z$ = standard normal deviate usually set at 1.96, which corresponds to the 95% confidence level ($z$ = 1.96), p = assumes proportion in the target population estimated to have a particular characteristic ($p$ = 0.5), $q$ = proportion of the estimation of population ($q = 1 - p$), $d$ = allowable maximum error in estimating a population proportion ($d$ = 0.05).

Moreover, the Simple Random sampling technique was adopted to successfully conduct 385 questionnaires at the household level of the displaced people (**Table 1**). Considering the representative sample size, the authors have distributed those samples statistical with the help of the following formula;

$$\text{Random sampling, Nj} = (\frac{\text{n}}{\text{N}})Ni$$

Where, Nj = represents the sample size, N = total population size, (N = ni + nii + niii +……+ nn), Ni = population size of study area, n desired sample size.

This study addresses scientific challenges in understanding climate change perceptions, impacts, and adaptation within Bangladeshi coastal fishing communities. A mixed-methods approach was employed to comprehensively analyze fisher communities' perceptions, expereicnes and adaptation strategies (**Table 1**).

While both quantitative and qualitative methods have inherent limitations, employing a mixed methods approach yields more robust findings than using either in isolation [47]. This study collected primary data through field visits and surveys. Quantitative and qualitative data were gathered using structured and semi-structured surveys, open-ended questionnaires, focus group discussions (FGDs), and both overt and covert observations.

**Table 1.** Community-led autonomous adaptation actions of Bangladeshi coastal communities.

| Domains of Impact | Adaptation Sectors | Description of Adaptation Strategies | Sources |
|---|---|---|---|
| Livelihoods | Diversification from Rice to to Non-Rice Crops | Diversification involves a shift to various non-rice crops, including jute, wheat, plums, and pulses. | Ayad [36] |
| | Diversification of income sources | Households diversify their income though wage employment, small businesses, artisanal work, and livestock rearing | Rathore et al. [37] |
| | Liquidation of Assets and Debt accumulation | Poor households frequently cope with weather-related crises by selling assets and taking out loans, strategies that can perpetuate long-term vulnerability. | Reggers [38] |
| | Gender Analysis of Livelihood Impacts | Women frequently engage in demanding external labor to contribute to household economic stability. | Sarker et al. [39] |
| | Mangrove Reforestation and Conservation | Mangroves support coastal resilience through a dual function: fostering sustainable livelihood opportunities and acting as a natural buffer against storms and erosion. | Schipper [40] |
| | Shifting of temporary services C | For instance, fishermen often engage in temporary employment outside of the fisheries sector. | Shameem et al. [41] |
| | Plinth Raising and Homestead Reinforcement | Communities in low-lying coastal and island regions proactively elevate their homesteads and plinths well above mainland standards as a primary defense against flooding. | Razowana et al. [42] |
| | Adoption of Climate-Resilient Housing | Community members collectively invest significant efforts in constructing concrete houses to enhance resilience against climatic threats. | Saha and Barua [43] |
| Communities in Vulnerable Coastal Areas | Community-Led Tree Planting | Planting trees around homes serves as a natural bio-shield, mitigating the impact of storm surges. | Abraham [44] |
| | Migration | Climate change acts driver of displacement, forcing populations to migrate from rural areas to urban centers. | Aram et al. [45] |
| Health | Adoption of Health-Promoting Behaviorss | Households employ seasonal health adaptation strategies-such as drawing on past experience, self-awareness of symptoms, and slef-care practices-to prvent illness from extreme heat, cold, or rain. | Sarkar et al. [46] |

Data collection was restricted to fishermen actively engaged in fishing operations. Quantitative data were collected and managed using the Kobo Toolbox Open Data Kit (ODK) platform to ensure reliability and accuracy. Qualitative data from open-ended responses were manually processed, coded and subsequently analyzed using the same platform. This research utilizes primary data from the fisheries ghat area, supplemented by secondary data from diverse sources, including English and Bengali literature, research papers, dissertations, newspapers, government records, and policy documents.

Marine fisheries are broadly categorized into two types: industrial and artisanal. The fishing gear and operational objectives determine the species and volume of catch. Industrial fisheries, also referred to as commercial fishing, are characterized by high capital investment and advanced technology to capture fish on a large scale within the national waters of the Bay of Bengal. In contrast, artisanal fishing is a small-scale, low-capital operation conducted by individual households. These fishers typically commute daily from the shore in small boats, operating within a range of approximately 8 kilometers.

The household survey targeted artisanal fishers for whom fishing is the primary occupation, a professionoften continued through generations or undertaken as their first employment. The average respondent was 55 years old, had seven years of formal schooling, and had been fishing as their primary livelihood for 35 years (**Table 2**).

**Table 2.** The socioeconomic traits of the homes that were surveyed.

| Traits | Average | SD |
|---|---|---|
| Age of Household Head | 55 | 9.2 |
| Years of formal Schooling | 1.50 | 1.850 |
| Monthly Income from Fishing | 20,500 BDT | 6300 BDT |
| Monthly Secondary Income | 6850 BDT | 1900 BDT |
| Father's Monthly Fishing Income | 12,350 BDT | 13,500 BDT |
| Second Household Member monthly Fishing Income | 12,200 BDT | 9200 BDT |
| Year of Fishing Experience | 35 | 11 |

It is mentioned that 1 BDT= **0.0082 USD**.

Focus Group Discussion (FGDs) were conducted with fishing communities to understand their lived experiences and identify shared perceptions of climate change adaptation methods . Each FGD session, which lasted approximately one hour, was scheduled at a time and location agreed upon in advance by the participating fishing villages. A minimum of eight willing and active fishermen attended each session.

Throughout the research, this study adhered to strictly social science ethical standards, with particular attention to the challenges of data collection in rural settings and the rights of all participants. Following data collection, the information was processed and analyzed using a combination of manual and computerized methods, primarily with MS Excel, and SPSS for quantitative data and MS word for qualitative analysis.

The authors utilized Analysis of Variance (ANOVA) and Principal Component Analysis (PCA) to analyze the study's findings on climate-adaptive technologies and their impact on fishermen's livelihoods.

A one-way ANOVA was employed to identify statistically significant differences in technology adoption levels and skills among various demographic groups of fishermen. This test was selected for its suitability in comparing mean scores across more than two groups. Three separate analyses were conducted:

1. Education × Technology Use: Fishermen's education levels (primary, secondary, higher, no education) were compared with their adoption of information and communication technology (ICT) tools.
2. Income × Skill Level: Monthly household income groups (< 5000, 5000–10000, 10000–20000, > 20000 BDT) were compared with levels of technological skill (high, medium, low).
3. Age × Years of Technology Use: Age categories (< 25, 25–35, 36–45, 46+) were compared with years spent using technology (at start of career, after three years, after five years).

Since the available data consisted of aggregated survey frequencies rather than raw individual responses, a synthetic dataset was reconstructed. This was done by proportionally distributing the categorical counts across respondents. All categorical variables were assigned numerical codes (e.g., Yes = 1, No = 0; High = 3, Medium = 2, Low = 1). The one-way ANOVA was then subsequently applied to these reconstructed datasets to test for significant differences between groups.

The general form of the one-way ANOVA model is:

$$Y\_ij = \mu + \tau\_i + \varepsilon\_ij$$

Where:

Y_ij = observed value of the dependent variable for the j-th subject in the i-th group; μ = overall mean of the dependent variable; τ_i = effect of the i-th treatment (group mean − overall mean).

ε_ij = random error term, assumed to be normally distributed with mean zero and variance σ^2.

The F-statistic is calculated as:

$$F = MS\_between/MS\_within = SS\_between/df\_between/SS\_within/df\_within$$

Where:

SS_between = sum of squares between groups ; SS_within = sum of squares within groups.

df_between = k - 1, where k = number of groups.

df_within = N − k, where N = total sample size.

Principal Component Analysis (PCA) is a dimensionality-reduction technique used to transform a large set of variables into a smaller on that still contains mots of the original information. It achieves this bu identifying new, uncorrelated variables known as principal comonents, which are linear combinations of the original variables that capture the maximum variance in the data.

The Principal Component Analysis (PCA) incorporated the following variables:

- Technology Adoption: Frequency of ICT use for fishing activities;
- Technology Type: The specific ICT devices and platforms employed;
- Usages Purpose: Application of ICT for communication, navigation, marketing, decision-making);
- Experience: Total years of technology use throughout the individual's career;
- Proficiency: Self-reported skill levels in operating these technologies.

Prior to the analysis. the aggregated frequency data were standardized to ensure all variables contributed equally to the component derivation. The PCA results are presented in in two parts: (1) the proportion of variance explained by each principal component, and (2) the factor loadings, which indicate the correlation of each original variable with the extracted components.

The principal component is defined as:

$$Z\_j = a\_j1 * X\_1 + a\_j2 * X\_2 + ... + a\_jp * X\_p$$

Where:

Z_j = the j-th principal component; a_j1, a_j2, ..., a_jp = loadings (weights) for the original variables X_1, X_2, ..., X_p; X_1, X_2, ..., X_p = the original variables (technology usage, years, skills, etc.)

The PCA procedure is based on solving the eigenvalue–eigenvector problem for the covariance matrix S: S a_j = λ_j a_j

Where:

S = covariance matrix of the variables; a_j = eigenvector corresponding to the j-th principal component; λ_j = eigenvalue representing the variance explained by Z_j.

Variance explained by each component is given by:

Var(Z_j) = λ_j

And the proportion of variance explained (PVE) is:

PVE_j = λ_j / Σ(λ_m) for all m = 1 to p.

**Figure 2** illustrates the flow chart of the research methodology.

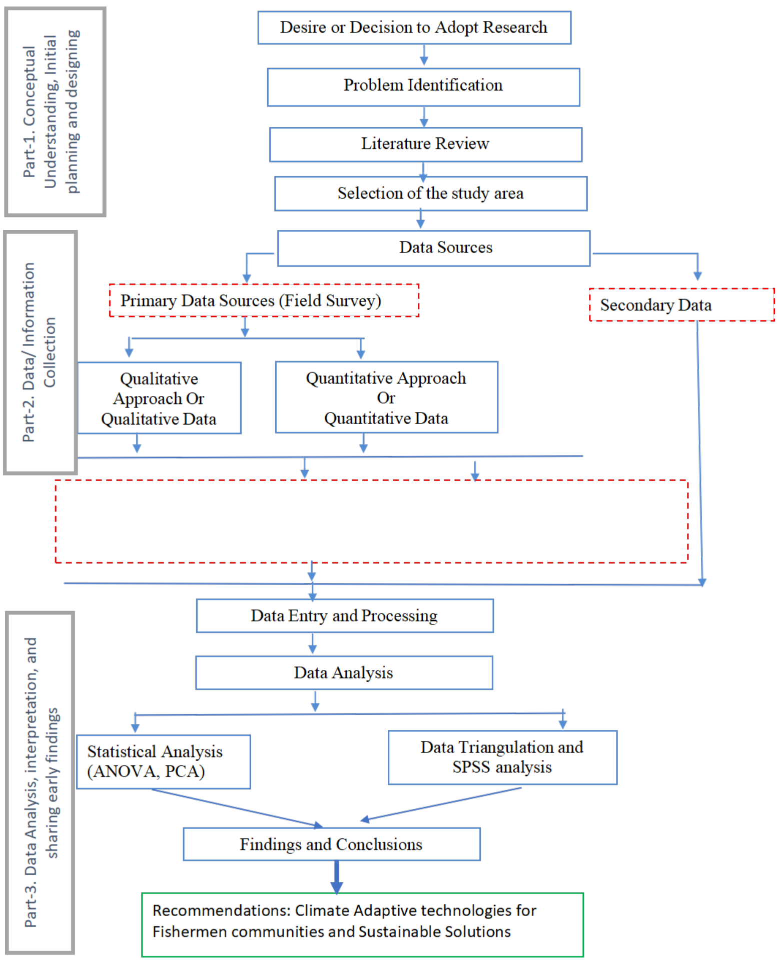


**Figure 2.** The flow chart of the research methodology.

## 4. Results

Climate change presents significant challenges for fishing communities, who must often venture into hazardous waters to secure their livelihood. In response, many fishermen are adopting modern, climate-resilient technologies.

These tools serve a dual purpose: mitigating personal risk from environmental hazards and enhancing fishing efficiency by locating fish stocks in the deep sea.

The study found that a majority of fishermen belong to low-income families, a factor that complicates livelihood sustainability and limits their ability to found their children's Education. Field survey data revealed that 30% of participants are illiterate, and 25% have no formal education. Furthermore, 39% of respondents have only completed primary education, while merely 6% have finished secondary education (see **Table 3**).

**Table 3.** Socioeconomic and demographic profile of the respondents.

| Socioeconomic & Demographic Profiles | N = 385 | Percentage |
|---|---|---|
| Educational status | | |
| Primary/Equivalent | 150 | 39 |
| High school/Equivalent | 20 | 6 |
| No formal education | 95 | 25 |
| Can sign only | 120 | 30 |
| Sex of the respondents | | |
| Male | 385 | 100 |
| Female | 0 | 0 |
| Age of the respondents | | |
| 19–30 | 78 | 26 |
| 31–40 | 101 | 35 |
| 41–50 | 70 | 25 |
| 51–60 | 18 | 8 |
| 61–Above | 5 | 6 |
| Marital status | | |
| Married | 246 | 74 |
| Unmarried | 22 | 18 |
| Widow | 4 | 8 |
| Religion of the respondents | | |
| Muslim | 355 | 86 |
| Hindu | 30 | 14 |
| Income of the respondents (in BDT) | | |
| 00–10,000 | 98 | 25 |
| 11,000–20,000 | 198 | 52 |
| 21,000–30,000 | 70 | 18 |
| 31,000–Above | 19 | 5 |
| Based on Income, fishermen define their Socioeconomic status as | | |
| Middle class | 23 | 15 |
| Lower middle class | 74 | 29 |
| Poor | 175 | 56 |
| Based on current Income, fishermen can secure sustenance for the whole year. | | |
| Yes | 175 | 45 |
| No | 210 | 55 |

Source: Fieldwork (Here, one USD is equal to 121 BDT approximately).

Fishermen reported several observable changes in local weather patterns, including a decline in total monsoon rainfall, fewer annual wet days, and an increase in short-duration heavy downpours. To evaluate these perceptions, their observations on precipitation changes were compared with 18 years (2000–2018) of rainfall data from a nearby meteorological station, focusing on the monsoon season (June–September). However, time-series analysis of this data showed no statistically significant trend in seasonal rainfall over this period at the at the 5% significance level.

According to the findings in **Table 4**, just over half of the fishermen (51%) reported using technology in their fishing activities. Among these technology users, the adoption was stratified: 21% relied solely on traditional methods, 17% used modern ICT-based tools, and 14% employed a hybrid of both. Mobile phones (41%) and GPS (38%) were the predominant ICT tools, in stark contrast to the minimal use of wireless sets (4%) and radar (3%). The primary application of this technology were navigation (30%), identifying fishing grounds (21%), family communication (19%), accessing weather forecasts (17%), and checking market conditions (13%) (**Table 4**).

Technology adoption occurred gradually; 36% of fishermen had used technology since the start of their careers, while 29% and 35% adopted it after three and five years, respectively. Despite this uptake, a significant confidence gap exists: only 18% considered themselves very skilled, contrasted with 44% who disagreed and 28% who were uncertain. In summary, while technological adoption is increasing, the sector is characterized by a strong persistence of traditional methods, underutilization of advanced tools, and a widespread lack of proficiency that hinders effective implementation (**Table 4**).

**Table 4.** The Nature of technology used by fishermen for fishing activities.

| Nature of Technology Used by Fishermen for Fishing | N = 385 | Percentage |
|---|---|---|
| Usage of any technology for fishing | | |
| Yes | 198 | 51 |
| No | 187 | 49 |
| Nature of technology used by fishermen | | |
| Modern technology (ICT) | 65 | 17 |
| Traditional technology (Capture tech.) | 80 | 21 |
| Both (Modern & Traditional) | 55 | 14 |
| Do not know | 20 | 5 |
| Do not use | 165 | 43 |
| Type of modern technology (ICT) used for fishing activities | | |
| Mobile phone | 160 | 41 |
| Global positioning systems (GPS) | 145 | 38 |
| Wireless sets | 15 | 4 |
| Radar | 12 | 3 |
| Others | **53** | **14** |
| Purpose of using ICT | | |
| To navigate the direction during fishing | 115 | 30 |
| Identifying a fishing location | 80 | 21 |
| To know the family situation & exchange information | 72 | 19 |
| To see the market position of fishing | 52 | 13 |
| For getting updated weather information | 66 | 17 |
| Years spent using technology for fishing purposes? | | |
| From the beginning of fishing | 140 | 36 |
| After 3 years of joining the fishing | 113 | 29 |
| After 5 years of joining the fishing | **132** | 35 |
| Very skilled at using technology | | |
| Agree | 70 | 18 |
| Disagree | 170 | 44 |
| Do not know | 45 | 12 |
| Strongly Agree | 37 | 10 |
| Strongly Disagree | **63** | 16 |

Note: N denotes the total number of respondents (fishermen) interviewed.

These findings underscore the profound socioeconomic vulnerability of fisherfolk, a condition driven by low Educational attainment, limited income, and seasonal food insecurity. To mitigate these challenges, policy interventions should prioritize expanding access to education and vocational training, diversifying income sources, and implementing robust social safety nets for lean seasons. Furthermore, promoting climate-resilient livelihoods-including alternative occupations, advanced fishing technology, and accessible microfinance-is essential to bolstering the long-term resilience of these communities against interconnected economic and environmental shocks.

Fishermen reported that tropical cyclones are increasing in both frequency and intensity, accompanied by more severe storm surges and flooding. This perception is substantiated by recent events; since 2013 alone, four major tropical cyclones—Mahasen (2013), Komen (2015), Roanu (2016), and Mora (2017)—have struck the Chittagong and Noakhali coasts. A longer-term historical view confirms this trend of significant cyclone activity in this region. Between 1970 and 2017, 17 out of 48 major storm surges in Bangladesh impacted the Chittagong-Noakhali coastline. Furthermore, in the in the last three decades (1990–2019), 10 out of 22 tropical cyclones that made landfall in Bangladesh hit this specific coastal segment.

The fishermen's report of salinity intrusion into previously non-saline zones, along with rising salinity in soil and water, were corroborated by soil surveys and water quality records, which confirmed a a trend of increasing soil salinity.

### 4.1. Effects of Climate Change and Extreme Events on Livelihoods, and Barriers to Adaptation

The findings of this study demonstrate that climate change and associated extreme events significantly impact the livelihoods and adaptive strategies of fishing communities. Respondents reported that climate shifts—including higher summer temperatures, reduced summer rainfall, and a delayed monsoon onset—have led to a decline in fish stocks in the Bay of Bengal. Focus Group Discussion (FGDs) confirmed that this issue is consistent across both in Salimpur and Sarikait coasts.

Communities also identified several direct threats to their lives and livelihoods. These include a rise in heat-relate illness and the depletion of fish populations, including formerly abundant species. The increasing frequency and intensity of tropical cyclones further disrupt fishing schedules, preventing regular access to the Bay of Bengal. While fishermen demonstrate a willingness to fish in these conditions, the acknowledge the severe dangers involved.

During cyclone seasons, rough seas often forced them to abort trips and return to shore. Additionally, infrastructure such as houses and roads is frequently damaged during these extreme weather events (**Table 5**).

**Table 5.** Responses of the Fishermen about the Challenges of their life and their strategies for resolving these solutions.

| Constraints on Livelihood Enhancement in the Fisheries Sector | Frequency (%) | Strategies for Livelihood Resilience | Frequency (%) |
|---|---|---|---|
| The Government has imposed a ban on fishing in the Bay of Bengal. | 60 (38) | It is recommended that the Government of Bangladesh (GoB) reconsider the current fishing ban. With the aim of either lifting or shortening it duration to alleviate economic hardship on fishing communities | 52 (36) |
| Don't make money off the investment | 35 (20) | Getting a loan from the GoB or NGOs | 40 (29) |
| Riverbank Erosion resulted in the lose of homes and agriculture land for local residents Riverbank erosion resulted in the loss of homes and agricultural land for local residents. | 16 (10) | Fishing the Bay during a time of great plenty | 15 (8) |
| There aren't enough fish. | 10 (6) | Getting legal help from the community | 8 (6) |
| **Problems that came up during the time of tropical cyclones** | **Frequency (%)** | **Strategies for adaptation to harsh climatic conditions** | **Frequency (%)** |
| Demolition of residences | 128 (38) | Installation of a tube well for potable water | 135 (22) |
| The fishing boat and net were ruined. | 90 (27) | Elevating the house's plinth to mitigate flooding | 125 (22) |
| Fishermen deceased in the Bay of Bengal | 30 (10) | Utilization of solar panels and biogas for energy generation | 122 (20) |
| Road degradation resulting from inundation by rainfall, tidal waters, and storm surges | 35 (10) | Rainwater harvesting as a source of safe drinking water | 112 (20) |

Source: Multiple Answers were employed in the data analysis.

The findings represented in the table demonstrate that fishermen in Cox's Bazar face a complex set of interconnected challenges impacting their livelihoods and safety. These issues are deeply rooted in economic, pressures, environmental degradation, and climatic risks.

Economically, mandatory fishing bans and poor returns on investment create significant hardship, forcing fishermen to depend on external aid and loans.

- Environmentally, riverbank erosion and declining fish stocks further threaten their income and food security.
- Climatically, intense tropical cyclones cause devastating damage to essential assets. Despite these pressures, the community has demonstrated notable resilience by adopting adaptation strategies such as rainwater harvesting, solar energy, and homested elevation.

These findings underscore the need for integrated policy interventions focused on providing robust financial support, enhancing disaster-resilience infrastructure, and implementing sustainable fisheries management. Furthermore, promoting the adoption of climate-resilient technologies is essential to help these communities adapt to ongoing environmental changes and secure their long-term sustainability.

## 4.2. Limits and Obstacles to Climate Adaptation

The study identified multiple barriers that constrain the adaptive capacity of fishermen to severe climatic conditions. The most frequently cited obstacles were insufficient household income and a lack of formal education (13% each), which collectively limit financial and knowledge resources during crises. Other significant barriers included unfavorable credit arrangements (12%) and misinformation leading to an underestimation of cyclone risks (11%). A further 10% of responses highlighted a deficit in technical skills, which impedes livelihood diversification (**Table 6**).

Additional challenges encompassed an increased incidence of tropical cyclones (8%), weak enforcement of fisheries regulations (7%), prolonged cyclone duration (7%), and limited market access (6%). Environmental and informational barriers, such as high wind velocity (3%), inaccurate weather forecasts (4%), and weak radio transmission (3%), further exacerbated community vulnerability.

Overall, the findings indicate that adaptation efforts are hindered by a combination of socioeconomic limitations (income, education, and credit), institutional weaknesses (poor regulation enforcement), and environmental-informational uncertainties (cyclones, unreliable forecasting). These interconnected barriers significantly diminish the resilience of fishing communities against climate-related hocks and stressors (**Table 6**).

**Table 6.** There are restrictions and obstacles to adapting to severe climatic conditions and events.

| Limits and Obstacles to Adaptation | Frequencies | Percentages (%) |
|---|---|---|
| Insufficient household income creates significant financial vulnerability during crises, limiting the capacity to respond effectively | 140 | 13 |
| Educational Deficit | 140 | 13 |
| Unfavorable credit terms can exacerbate financial distress during crises. | 135 | 12 |
| Misinformation about cyclone forecasts sometimes led to public disbelief, resulting in a failure to take protective measures. | 128 | 11 |
| Limited technical skills constrain livelihood diversification | 119 | 10 |
| Increased Frequency and Intensity of Tropical Cyclones | 95 | 8 |
| Inadequate enforcement of fishing laws undermines sustainable resource management and compliance. | 90 | 7 |
| Prolonged duration of tropical cyclones | 90 | 7 |
| Inaccessibility to seafood markets | 75 | 6 |
| Elevated wind velocity of tropical cyclones | 67 | 5 |
| Inaccurate weather forecasts heighten the risk to lives. | 50 | 4 |
| Weak radio transmissions hinder the acquisition of precise information. | 30 | 3 |
| Total | 1.169 | 100% |

Source: Multiple Answers were employed in the data analysis.

## 4.3. Contentment with Diverse Facets of Existence

The results reveal varying levels of satisfaction among fishermen across key life domains: income, socioeconomic status, and social relationship (**Table 7**). Economic well-being emerged as the primary concern. A large majority (72%) reported only average satisfaction with their income while 30% were satisfied, and a small percentage (2%) expressed dissatisfaction. Notably, no respondents reported being very satisfied, indicating widespread economic instability.

In contrast, perceptions of their broader socioeconomic condition were more positive with a significant majority (84%) expressing satisfaction and the remainder (22%) rating it as average. No dissatisfaction was reported in this domain, suggesting a distinction between immediate financial struggles and their overall perceived social standing.

Social relationships scored the highest level of satisfaction, with 86% of fishermen satisfied and 6% very satisfied. This strong sense of community cohesion, with no reported dissatisfaction, appears to serve as a critical coping mechanism and a key source of resilience against economic hardships. This robust social and religious network in the villages of Salimpur and Sarikait underscores the importance of community bonds for overall well-being (**Table 7**).

**Table 7.** Satisfaction with Income, social standing, and relationships with neighbors and others.

| Different Parts of Living | Very Satisfied | Satisfied | Average | Unsatisfied | Very Unsatisfied | Total |
|---|---|---|---|---|---|---|
| Revenue | - | 45 (30) | 99 (72) | 5 (2) | – | 140 (100) |
| Socioeconomic status | – | 115 (84) | 40 (22) | – | – | 140 (100) |
| Relationship with the neighbors and others | 10 (6) | 120 (86) | 25 (15) | – | – | 140 (100) |
| Total | 10 (6) | 280 (200) | 164 (109) | 5 (2) | – | – |

Based on the findings in **Table 8**, the study examined fishermen's exposure to hazards, their coping strategies, and the role of technology in risk reduction. A majority of respondents (74%) reported encountering hazards during fishing, with the most common being cyclones (18%), sudden storms (14%), and natural disasters (12%). Other significant challenges included worsening weather (9%), turbulent seas or heatwaves (8%), and heavy rainfall (6%). A small percentage (4%) cited operational issues like equipment failure.

When facing these hazards, fishermen employed a rage of coping strategies. The most frequent were relying on prior experience and knowledge (10%), halting fishing operations to return to shore (9%), and using technology such as navigation aids or communication devices (8%). Other reported measures included seeking help from others (7%), changing course (7%), using survival tools (5%), and being rescued by fellow fishermen (7%).

The Adoption of climate-resilient technology remains limited, with only 31% of respondents reporting use and a majority (69%) having no experience with such tools. Among adopters, mobile phones (18%) and GPS devices (15%) were the most common, while the internet (4%) and social media (6%) saw minimal uptake. It is noteworthy that over half of the fishermen (54%) stated they had never used any form of climate-resilient technology.

Perception of Information and Communication Technology (ICT) were mixed but leaned positive. A significant majority (65%) agreed that mobile phones provide essential weather updates, and 59% found mobile and remote sensing technologies accurate for hazard prediction. Daily forecasts were considered reliable by 62% of respondents. However, a substantial portion of the community-between on-fifth and one-third remained skeptical or uncertain about the reliability of these technologies.

In summary, while foundational ICT tools like mobile phones and GPS are being gradually integrated, adoption is not yet widespread. Traditional coping mechanisms remain vital, and trust in technology, through generally favorable, is not universal. The findings suggest that barriers such as cost, access, and digital literacy hinder broader adoption. To enhance climate resilience, targeted interventions focusing on affordable access, practical training, and reliable service infrastructure are critically needed (**Table 8**).

**Table 8.** Influence of climate-resilient technology to overcome hazards during fishing activities.

| Impact of Climate-Resilient Technology to Overcome Hazards | N = 385 | Percentage |
|---|---|---|
| Face hazards during fishing? | | |
| Ye | 285 | 75 |
| No | 100 | 2 |
| Type of hazard faced by fishermen | | |
| Cyclone | 68 | 18 |
| A sudden storm | 55 | 14 |
| Natural disaster | 45 | 12 |
| Weather getting worse | 35 | 9 |
| Turbulent waves and heat waves | 33 | 8 |
| Deep cloud and massive rainfall | 24 | 6 |
| Equipment shortage and problems | 15 | 4 |
| Others | 20 | 5 |
| Do not face any hazards | 90 | 24 |
| Fishermen overcome hazards | | |
| By previous experience and knowledge | 40 | 10 |
| Stop fishing and return to the shore | 32 | 09 |
| By using technology | 29 | 8 |
| By asking for help | 26 | 7 |
| By altering direction | 25 | 7 |
| Using some survival tools | 20 | 5 |
| Going to a safe place | 21 | 5 |
| Rescued by other fishermen | 28 | 7 |
| Cannot overcome it always | 19 | 5 |
| Others | 25 | 6 |
| Do not face any hazards | **120** | **31** |
| Ever used climate-resilient technology to overcome hazards | | |
| Yes | 120 | 31 |
| No | **265** | 69 |
| Climate-resilient technology that fishermen depend on to escape from hazards | | |
| Mobile phone | 68 | 18 |
| Global positioning systems (GPS) | 58 | 15 |
| Internet | 15 | 4 |
| Social Media | 25 | 6 |
| Others | 10 | 3 |
| Never used climate-resilient technology | **209** | **54** |
| Fishermen use a mobile phone to access the latest weather updates before leaving for the sea to reduce risk. | | |
| Agree | 195 | 52 |
| Disagree | 65 | 17 |
| Do not know | 55 | 14 |
| Strongly Agree | 50 | 13 |
| Strongly Disagree | 20 | **5** |
| Mobile and remote sensing accurately predict future natural hazards and help in reducing risk exposure. | | |
| Agree | 190 | 49 |
| Disagree | 70 | 18 |
| Do not know | 75 | 20 |
| Strongly Agree | 40 | 10 |
| Strongly Disagree | 10 | **3** |
| ICT provides an update on the weather forecast | | |
| Agree | 210 | 54 |
| Disagree | 50 | 13 |
| Do not know | 43 | 11 |
| Strongly Agree | 67 | 18 |
| Strongly Disagree | 15 | **4** |
| Fishermen can get an update about the weather forecast daily | | |
| Agree | 200 | 52 |
| Disagree | 90 | 23 |
| Do not know | 35 | 9 |
| Strongly Agree | 40 | 10 |
| Strongly Disagree | 20 | **6** |

Note: N denotes the total number of respondents (fishermen) interviewed.

**Table 8.** *Cont.*

| Impact of Climate-Resilient Technology to Overcome Hazards | N = 385 | Percentage |
|---|---|---|
| Technology warns about the upcoming hazards during fishing | | |
| Agree | 190 | 49 |
| Disagree | 80 | 21 |
| Do not know | 60 | 15 |
| Strongly Agree | 45 | 12 |
| Strongly Disagree | 10 | **3** |
| ICT helps with climate change adaptation and weather risk reduction | | |
| Agree | 190 | 49 |
| Disagree | 50 | 13 |
| Do not know | 65 | 18 |
| Strongly Agree | 60 | 15 |
| Strongly Disagree | 20 | **5** |
| ICT tools enhance fishermen's self-efficacy and adaptation motivation. | | |
| Agree | 195 | 51 |
| Disagree | 55 | 14 |
| Do not know | 80 | 21 |
| Strongly Agree | 45 | 12 |
| Strongly Disagree | **10** | **2** |
| ICT used for disaster communication and management in fisheries | | |
| Agree | 200 | 52 |
| Disagree | 45 | 12 |
| Do not know | 70 | 18 |
| Strongly Agree | 50 | 13 |
| Strongly Disagree | **20** | **5** |

Note: N denotes the total number of respondents (fishermen) interviewed.

## 4.4. ANOVA Analysis

The one-way ANOVA tests examined whether differences in Education, Income, and Age significantly affected technology adoption or skills.

- Education × Technology Use: The results showed no statistically significant differences between education levels (primary, secondary, higher Education) in terms of technology adoption. This suggests that educational background is not a determinant factor in whether fishermen use modern technologies. It may indicate that other factors, such as financial resources, access to technology, and peer influence, play more significant roles than Education.
- Income × Skill Level: There were also no significant differences between income groups and ICT skill levels. This implies that higher Income does not necessarily lead to higher proficiency in using ICT tools. Fishermen in low-income groups seem to use mobile phones and GPS as effectively as those in higher-income groups, reinforcing the idea that economic resources do not always correlate directly with technology use.
- Age × Years of Technology Use: No significant differences were found between age groups and years of technology usage. While younger fishermen are expected to adopt technology more readily, the data suggests that older generations may still be using technology at similar rates. The slow adoption process could be linked to external factors such as training opportunities and technological availability rather than Age alone (**Table 9**).

**Table 9.** ANOVA Analysis based on the present study findings.

| Test | Degrees of Freedom (df) | F-statistic | *P*-value | Interpretation |
|---|---|---|---|---|
| Education × Technology Use | 3, 381 | 0.007 | 0.999 | No significant difference |
| Income × Skill Level | 3, ~381 | 0.005 | 1.0 | No significant difference |
| Age × Years of Tech Use | 3, ~381 | 0.005 | 1.0 | No significant difference |

*Note. All ANOVAs were based on reconstructed data from aggregated survey counts.

The ANOVA results indicated no statistically significant relationship between the selected socioeconomic factors and technology adoption or skill levels among the studied fishermen ( all $p$-values > 0.05). Specifically:

- Education and Technology Use ($p$ = 0.999): No significant association was found between education level and the extent of technology adoption.

- Income and Skill Level ($p$ = 1.0): Income level showed no significant correlation with self-reported technology proficiency.
- Age and Years of Technology Use ($p$ = 1.0): A fisherman's age did not significantly predict the duration of their technology use.

So, it was found that since all the $P$-values are greater than 0.05, consequently, the null hypothesis for all three factors could not be rejected. These findings suggest that in this specific context, conventional socioeconomic indicators are not the primary drivers of technological integration. Instead, external enablers such as targeted training, access to affordable technology, and reliable infrastructure may be more influential in the adoption and development of technological skills.

### 4.5. PCA Analysis

PCA identified three key components that explain the variance in fishermen's technology usage patterns.

- PC1 (Technology Adoption and Purpose): This component emphasized the relationship between technology use and its purposes (e.g., navigation, communication). It shows that fishermen who adopt technology are more likely to use it for practical reasons related to fishing operations.
- PC2 (Skill and Years of Use): This component captured the effect of skill development over time, suggesting that those with greater experience using technology also report higher levels of technology skill.
- PC3 (Nature of Technology): This component distinguished the types of technology used, noting that mobile phones and GPS are more common, while radar and sonar devices remain underutilized. This reflects the barriers to more advanced technology adoption due to cost and accessibility (**Tables 10** and **11**).

**Table 10.** Explained Variance by Principal Components.

| Component | Variance Explained (%) |
|---|---|
| PC1 | 95.19 |
| PC2 | 4.81 |
| PC3 | 0.0 |

**Table 11.** Component Loadings of the Findings of the Present Study.

| Component | Tech Use | Nature | Purpose | Years | Skill |
|---|---|---|---|---|---|
| PC1 | 0.458 | 0.433 | 0.455 | 0.433 | 0.455 |
| PC2 | 0.0 | −0.667 | 0.234 | 0.667 | −0.234 |
| PC3 | −0.847 | 0.377 | 0.106 | 0.357 | 0.048 |

*Note. PCA was performed on a synthetic dataset derived from aggregated frequencies of technology adoption, Nature, purpose, years of use, and skill levels.

The findings indicate that while climate-resilient technology (especially mobile phones and GPS) has the potential to increase fishing efficiency, improve productivity, and reduce risks from climate change, barriers such as limited infrastructure, financial constraints, and market access still inhibit the widespread adoption of advanced technologies. The ANOVA and PCA results suggest that socioeconomic factors like Income, Education, and Age do not strongly influence technology use. Instead, external factors such as training opportunities and access to affordable technology are more critical.

- PC1 shows moderate positive loadings across all variables, meaning it represents a combination of technology use, Nature of technology, purpose, years of use, and skill.
- PC2 has significant negative loadings on Nature (−0.667) and positive loadings on Years (0.667), suggesting it captures the relationship between skill development and experience.
- PC3 has strong negative loadings on Tech Use (−0.847), indicating that underutilization of advanced technology (e.g., radar, sonar) is captured here.

## 5. Discussion

This study investigates the types of technologies adopted by fishermen and their role in promoting sustainable livelihoods, with a specific focus on how climate-resilient information and communication technologies (ICTs) help mitigate fishing-related risks. The findings indicate that despite their potential benefits, the adoption of these technologies remains limited. This result aligns with prior research suggesting that fishermen in developing coastal regions are often hesitant to embrace new technologies due to constraints related to cost, accessibility, and availability [47].

Despite the growing use of GPS and mobile phones, the high cost of modern equipment ensures that traditional fishing knowledge remains prevalent [48]. The data show that 22% of fishermen rely solely on conventional methods, while 14% use a hybrid of traditional and contemporary techniques. This pattern indicates a slower adoption rate compared to other regions, such as China, where robust infrastructure and greater resource availability have accelerated technological integration [49].

This pattern aligns with generational trends observed in prior research, where younger fishermen demonstrate a greater propensity to adopt modern tools, while older generations maintain reliance on traditional methods [50]. The slower adoption rate in Chattogram contrasts with regions like China, where superior infrastructure and resource availability have facilitated more widespread technological integration [51]. The result in Chattogram is a gradual socio-technical transition, characterized by a hybrid model. This approach leverages the reliability of modern ICTs while preserving invaluable, time-tested indigenous knowledge, creating a resilient adaptation strategy.

A clear divergence in adoption and skill levels persists between early and late adopters. In Chattogram younger fishermen, who are often exposed to technology at the outset of their careers, constitute 40 percent of early users-a trend consistent with observations in in coastal Malaysia [51]. Conversely, older fishermen frequently encounter adaptation barriers, including limited training access and deeply ingrained traditional practices. This is reflected in the survey, where 54% of respondents reported insufficient proficiency in using modern tools, underscoring the critical need for targeted training programs to ensure broader and more effective technological integration [52].

Information and Communication Technology (ICT) has been integrated into the fishing sector to enhance operational efficiency by improving communication and facilitating the exchange of weather and market. Tools such as GPS, sonar, and mobile phones provide timely updates that help increase fishing efficiency, reduce uncertainty, and in some cases, raises revenues. A majority of respondent (63%) reported that ICT had improved their livelihoods, primarily by streamlining daily operations, improving market access , and providing reliable weather forecasts [53].

The finding of this study confirm that ICT tools, especially GPS and mobile phones, significantly contribute to sustainable fishing practices, greater productivity, and enhanced safety. However, challenges persist. Approximately 37% of fishermen cited obstacles such as uneven access, financial constraints, and a lack of technical expertise, which prevent the full utilization of these technologies. Furthermore, while 31% of respondents believed that ICT enables them to market their catch directly, 38% still depend on intermediaries. This indicates broader structural issues within coastal economies, where barriers to market access continue to limit the potential benefits of technological adoption [54].

In addition to boosting productivity, fishermen are increasingly using ICT to access meteorological and climate-related information. Early warning systems delivered via mobile devices have been instrumental in reducing vulnerability to cyclones, high waves, and other hazards. A majority of fishermen agreed that these tools have improved the stability and sustainability of their livelihoods. This aligns with findings from other regions, where ICT has enhanced safety by providing early warnings, navigational aid, and emergency communication [55].

Despite these benefits, adoption of climate risk mitigation remains low in Chattogram, with only 33% of fishermen using ICT for this purpose. This rate is substantially lower than in other countries like the Philippines, highlighting a significant adoption gap. The disparity suggests that without improved infrastructure, targeted training, and financial support, fishermen in disadvantaged regions will continue to be excluded from the full protective benefits of technology. Therefore, evidence indicates that raising awareness and implementing localized training programs are critical to enabling these communities to harness ICT more effectively for climate adaptation [56].

A matrix of climate-adaptive technologies demonstrates their role in supporting the resilience of fishing livelihoods in coastal Bangladesh (**Table 12**). These innovations address risks across the fishing cycles:

- Early-warning and communication systems: Systems such as SMS alerts, VHF radios, community sirens enable the rapid dissemination of storm and cyclone information, significantly reducing losses at sea.
- Maritime Safety: Technologies like GPS trackers and the Automatic Identification System (AIS) enhance navigation accuracy and streamline rescue operations, thereby improving survival rates and protecting assets.
- Post-Harvest Management: Innovations including solar dryers and sanitary processing facilities reduce spoilage and improve product quality, increasing market value and providing significant benefits, particularly for women in processing roles.
- Supply Chain Integration: Cold-chain technologies help maintain freshness and strengthen market linkages.
- Product Diversification: Climate-smart aquaculture, such as cultivating saline-tolerant species and using cage culture, provides crucial income diversification.
- Market and Information Access: Digital platforms deliver real-time data on weather, fish availability, and market prices, empowering fishermen to make informed decisions in local and regional markets (**Table 12**).

**Table 12.** Matrix: Climate-Adaptive Technologies & Their Influence on Fisherfolk.

| Technology | Primary Function | Mechanisms of Change | Direct Benefits | Livelihood Outcomes | Cross-Cutting Issues |
|---|---|---|---|---|---|
| Early-warning & Communication (SMS, VHF radios, sirens, community flags) | Disseminates cyclone & storm alerts | Improves preparedness, evacuation, and decision-making | Timely return from sea, reduced casualties, safer assets | Fewer injuries/deaths, reduced loss of boats & nets, more predictable fishing days | Access inequality (literacy, mobile coverage), women's exclusion, trust in info |
| On-water Safety Tech (GPS, AIS trackers, safety equipment, departure rules) | Guides navigation & tracks vessels | Reduces uncertainty, enhances rescue capability | Safer fishing trips, lower accident risk | Greater survival rates, less loss of capital | Cost, maintenance, fisher awareness/training |
| Post-harvest Tech (Solar/tunnel dryers, insulated boxes, hygienic processing) | Reduces spoilage & contamination | Extends shelf life, improves quality, and increases bargaining power | Lower post-harvest loss, premium prices | Higher net Income, stronger role for women processors | Initial cost, training, and cultural acceptance of "new" dried fish |
| Cold-chain Innovations (Solar ice plants, micro-cold storage, insulated transport) | Keeps fish fresh from catch to market | Slows spoilage, improves market timing | Better product quality, higher value sales | Increased Income, more stable supply chain | Energy reliability, affordability, and institutional support |
| Climate-smart Aquaculture (Saline-tolerant species, pens/cages, feed & water mgmt.) | Diversifies income beyond capture fisheries | Provides alternative production during lean/closed seasons | Additional revenue stream, local food availability | Reduced dependency on the open sea, greater resilience | Land/water rights, investment cost, disease risk |
| Digital Advisory & Market Platforms (apps, SMS services, price info) | Provides real-time data & market trends | Improves decision-making & timing of sales | Better prices, informed harvest schedules | Higher profit margins, reduced exploitation by middlemen | Digital literacy, the gender gap in phone use |

This study demonstrates the transformative potential of climate-resilient technologies in enhancing the sustainability and resilience of coastal fishing communities in Chattogram. These tools facilitates crucial adaptation to climate change by delivering timely weather updates and hazard alerts, thereby improving the safety and stability of fishermen's livelihoods. While the report underscores the significant benefits of these technologies, it also identifies key challenges-such as accessibility, cost, and digital literacy-that must be addressed to enable broader and more equitable adoption.

## 6. Conclusions

This study illuminates the complex vulnerability of fisherfolk communities on Bangladesh's south-eastern coast, who are navigating a confluence of climatic and non-climatic stressors. Scientific data collaborates their observations of rising temperatures, sea levels, and cyclone intensity, through not their reports of declining monsoon rainfall. Beyond these environmental pressures, there livelihoods are further strained by a web of challenges including restrictive regulations, economic precarity, and competition form commercial fisheries.

The fishermen stated that they do not solely contend with climate stress; instead, they face a multitude of non-climatic challenges, such as government regulations, lower profits, bank erosion, and the dominance of commercial fishers, all of which complicate their efforts to sustain a living. Despite these compounded stresses, a strong commitment to their profession persists among fishers, highlighting a critical opportunity: policy interventions must extend beyond climate adaptation to include broader risk-reduction strategies tailored to this resilience workforce. Looking forward as climate projections indicate a worsening scenario, a dual-focused approach is essential. This involves implementing localized adaptation measures while leveraging the transformative potential of Information and Communication Technology (ICT). Tools such as early warning systems and navigational aids can significantly enhance individual and community capacity, safeguarding lives and livelihoods by providing critical, real-time information to navigate the escalating risks at sea.

This involves implementing localized adaptation measures while leveraging the transformative potential of Information and Communication Technology (ICT). Tools such as early warnings systems and navigational aids can significantly enhance individual and community capacity, safeguarding lives and livelihoods by providing critical, real-time information to navigate the escalating risks at sea.

To enhance the resilience of coastal fishing communities, the authors are proposed following climate-adaptive technological and policy solution which are as follows:

- Disseminate user-friendly alerts in Bangla and local dialects via mobile SMS, community loudspeakers, and affordable, waterproof VHF radios
- Promote GPS devices and smartphone-based navigation apps (e.g., Khola) for safer route planning, and locating fishing grounds.
- Support the construction of storm-resistant boats with sealed buoyancy chambers, and promote affordable motorization for quick returns to shore.
- Established community-owned solar dryers and solar-powered cold storage to reduce spoilage and reliance on unstable grid power .
- Introduce hygienic, raised platform drying systems to improve product quality.
- Promote salinity-tolerant aquaculture (e.g., tilapia, shrimp, coral) and alternative livelihoods like beekeeping, duck rearing, and saline-tolerant crop cultivation.
- Install managed aquifer recharge (MAR) systems and community-scale rainwater harvesting with solar pumps for safe drinking water.
- Promote and subsidize elevated storm-resistant housing designs.
- Undertake mangrove restoration to act as a natural storm barrier and replenish fish stocks.
- Involve fishers (men and women) in the co-design of technologies from the outset.
- Provide soft loans, microcredit, grants, index-based insurance tailored to people experiencing poverty.
- Ensure equitable benefits for women by placing assets like solar dryers under the control of women's cooperatives.
- Empower Community-Based Organizations (CBOs) to manage shared resources and advocate for community rights.
- Foster collaboration between government agencies, NGOs, the private sector, and communities.
- Avoid environmentally degradation technologies and ensure solutions do not exacerbate wealth inequalities. .
- Preserve and integrate valuable indigenous knowledge with new technologies.

The implementation of these technologies can transform a narrative of vulnerability into one of resilience, protecting lives, securing assets, and diversifying incomes. However, profound challenges remain. Poverty, illiteracy, and low digital literacy hinder adoption, as many fishers lack knowledge of basic ICT tools such as mobile phones, GPS, and the internet. Overcoming these barriers requires a concerted effort from governmental and non-governmental institutions to provide formal education and hands-on training. By building human capacity alongside technological infrastructure, these communities can not only cope with climate change but truly thrive despite it.

## Author Contributions

P.B. was responsible for conceptualization the research, literature review, methodology framework and data analysis. N.N. was responsible for manuscript writing, editing the manuscript. All authors have read and agreed to the published version of the manuscript.

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## Conflicts of Interest

The authors declare no conflict of interest.

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