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Water Quality Affects Socioeconomic Traits of Climate Vulnerable Coastal People: Case Study on Dacope and Mongla

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Abstract Bangladesh's coastal regions, particularly Dacope and Mongla, are increasingly affected by environmental degradation driven by climate variability, salinity intrusion, and environmental stress, threatening both ecosystems and livelihoods. This study investigates the relationship between water quality and the socioeconomic traits of vulnerable communities in these areas. In-situ measurements of temperature, salinity, total dissolved solids (TDS), and electrical conductivity (EC) were conducted across multiple stations alongside household surveys capturing income patterns, health outcomes, migration intentions, and adaptive capacity. Results show water temperatures between 28.5°C and 28.9°C, with salinity peaking at 18.9 PSU, TDS reached 11,710 mg/l, and EC levels were as high as 14,770 µS/cm, indicating degraded water conditions. These conditions are closely associated with adverse socioeconomic outcomes, including widespread skin diseases affecting approximately 68% of respondents, declining fisheries productivity, and strong livelihood insecurity. Economic stress is evident, with 92% of Mongla residents expressing intentions to migrate and 78% seeking alternative livelihoods due to reduced income opportunities. Educational attainment remains low, with only 2-3% of households accessing higher education, limiting adaptive capacity and climate literacy.

These findings emphasize the need for integrated water management, livelihood diversification, and climate education to enhance resilience in Bangladesh's coastal communities. Evidence-based interventions addressing water quality degradation can play a critical role in reducing

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health risks, stabilizing livelihoods, and strengthening long-term climate adaptation in highly vulnerable coastal regions.

Keywords: climate vulnerability, water quality, socioeconomic impact, livelihood resilience, adaptation strategies

1. INTRODUCTION

The delicate balance of ecosystems is increasingly threatened by shifting climate patterns, which profoundly affect environmental systems, economic stability, and public health. A shift in the existing flora, fauna and natural systems makes the atmosphere suitable for human existence and biodiversity (Saini, 2023). Climate change significantly impacts water quality because extreme weather events like droughts and heavy rainfall occur more frequently (Huang & Fan, 2023). These extreme events can wash out surface pollutants during heavy rainfall, affecting neighboring water bodies, while droughts can lead to water scarcity and deterioration in water quality (Vliet, 2023). Additionally, climate change can alter water's ecological balance through changes in flow patterns, nutrient concentrations, and phytoplankton blooms, resulting in variations in dissolved oxygen levels and algal blooms (Radhapyari et al., 2021) Rising sea levels and salinization also contribute to the reduction of freshwater resources and changes in water quality (Shukla et al., 2023). Furthermore, climate change can affect water temperature, stratification, sediment nutrient release, and ice conditions, all of which impact the eutrophication of standing waters, and increased precipitation and discharge can lead to an increase in the concentration of chemical pollutants in surface water (Saberi et al., 2023).

Climate change triggers considerable issues for environmental stewards, particularly affecting the water bodies. Research has mainly focused on the availability and volume of water rather than the quality. Adaptation approaches for water quality have been conventional, primarily focusing on an incremental bag of tricks. However, these strategies must be more resilient to address significant future climate changes (Bartlett & Dedekorkut-Howes, 2023). Water quality practices, such as those used to mitigate urban water, agriculture, and forestry impacts, depend on weather and climate. Climate change will alter the function of these practices, and reducing the risk of effects will require adaptive planning. The resilience of practices depends on their sensitivity to changes in climatic drivers and their adaptability (Johnson et al., 2022). Climate change can affect water quality through various mechanisms, including changes in temperature, rainfall patterns, and extreme weather events. These changes can alter ecological balance, nutrient availability, and dissolved oxygen levels. Rising sea levels can also result in salinization of freshwater resources. The impact of climate change on water quality can harm food security and agricultural communities in arid regions (Srivastav et al., 2021). Environmental factors such as carbon dioxide emissions, humidity, and soil moisture can affect the response characteristics of water quality to climatic factors. These factors can enhance or stabilize the climate response of different water quality parameters.

Understanding these relationships can guide water environment management in the context of climate change (Hafeez et al., 2022).

The impact of climate change on freshwater systems typically encompasses heightened evaporation rates, resulting in increased rainfall and flooding in wetter areas, as well as diminished water availability in drier regions. The rise in temperature and fluctuations in precipitation can further intensify water pollution and affect ecosystems, human health, and the reliability of water supplies. In Khulna, the water-related consequences of climate change include regular waterlogging during heavy rainfall events (Sarkar et al., 2021). Furthermore, climate change and rising sea levels negatively impact the groundwater quality in the coastal region of Khulna (Rozhkova & Guo, 2019).

Climate change significantly impacts the variables and processes that affect water quality and freshwater biodiversity, which can also affect the structure and functioning of freshwater ecosystems by altering water discharge, water level, retention time, and other essential factors (Humlum et al., 2011). Click or tap here to enter text. Unsafe drinking water and waterborne diseases are responsible for 80% of illnesses in developing countries, making them more vulnerable to the effects of climate change (Abedin et al., 2018). The World Health Organization states that protecting human health from climate change is one of the century's most significant challenges because freshwater shortages are predicted to occur worldwide due to changes in temperature, precipitation, and sea level rise, endangering human health (Dao et al., 2024).

Intensification of climate variability, catastrophic occurrences like floods, droughts, and storms, coupled with the slow rise in sea level and temperatures, are associated with climate change, which Bangladesh experiences (Khan et al., 2011). Coastal areas are more susceptible to certain natural events due to sea level rise, inadequate rainfall in winter, high evaporation rates, and various disastrous events like cyclones and storm surges. These events can severely impact water infrastructure and supply systems. For instance, floods or tidal surges can inundate tube wells, ponds, and water bodies, contaminating natural sources of freshwater (*Water, Sanitation and Hygiene: The Foundation for Building Resilience in Climate-Vulnerable Communities | WASH Matters*, n.d.). Waterborne diseases are a major cause of concern in Bangladesh accounting for 24% of all deaths in the country in 2007 (Reid et al., 2007) and later found 8.1% (Bilal et al., 2023). According to a recent estimate by the World Health Organization (WHO), 58% of all diarrheal illnesses in middle- and low-income nations can be caused by unsafe potable water (34%), hygiene (20%), and sanitation (19%) (*World Water Day 2021*, n.d.). The Sundarbans mangroves in Bangladesh have been found to have low or non-significant pollution levels and fair water quality, except for certain constraints (Sowrav et al., 2023). The impacts of climate change on the Sundarbans include water-related problems, increasing levels of salinity, decreasing freshwater supply, irregular rainfall, and sea level rise, which have contributed to the destruction of the mangrove forest (Sanaul & Mondal, n.d.). Another study explores the prevalence of agricultural nonpoint source pollution worldwide from farming activities, adding silt, nitrates, and phosphorus in water bodies (Zhao et al., 2019).

This study aimed to measure the water quality of Dacope and Mongla and the associated socioeconomic consequences due to the water quality. Water quality has been measured by addressing temperature, salinity, pH, total dissolved solids (TDS), and electrical conductivity (EC). This research further investigated climate literacy and adaptation strategies for the respondents in the study areas to overcome the challenges of degraded water quality. This paper will help the policymakers to solve water-related issues in those climate-vulnerable areas and take necessary interventions to reduce economic losses, address salinity problems and cure skin diseases. This study uniquely addresses the critical gap in understanding the intricate interplay between specific water quality parameters and the multifaceted socioeconomic vulnerabilities of coastal communities in Dacope and Mongla. By integrating in-situ water quality measurements with comprehensive household surveys on health, livelihoods, adaptive capacity, and climate literacy, this research provides novel, localized empirical evidence. This granular analysis moves beyond broad observations to reveal precise, unaddressed challenges and community perceptions, offering a robust foundation for developing targeted, evidence-based interventions and policy recommendations to enhance resilience against the dual impacts of climate change and water degradation in these highly susceptible regions. Accordingly, the objective is to evaluate key river water quality parameters and examine their direct links with health outcomes, livelihood conditions, climate literacy, and adaptive responses of climate-vulnerable coastal communities in Dacope and Mongla, Bangladesh, to inform targeted water management and adaptation interventions.

2. STUDY AREA

The study area encompasses the Sundarbans, a UNESCO World Heritage site and the largest mangrove forest in the world, located in the southwestern coastal region of Bangladesh. This region spans the Khulna and Bagerhat districts which are most vulnerable to sea level rise and climate change on the southwest coast of Bangladesh. The last living communities adjacent to the Sundarbans are from the Dacope thana and Mongla thana, both directly affected by the water quality of the Pashur River on the east and west banks of the river (Figure 1). The Sundarbans is a vital ecological zone (S. N. Islam, 2019), characterized by a unique intertidal ecosystem that supports a diverse array of flora and fauna, including the endangered Bengal tiger (*Panthera tigris tigris*) and numerous species of fish, crustaceans, and birds.

The significance of the Sundarbans extends beyond its ecological value. It is crucial in protecting inland areas from tropical cyclones, storm surges, and coastal erosion, acting as a natural barrier against climate change impacts. Additionally, the region supports the livelihoods of millions of people through fisheries, forestry, and eco-tourism, which fuel our nature-based economy, making it an area of economic and environmental importance.

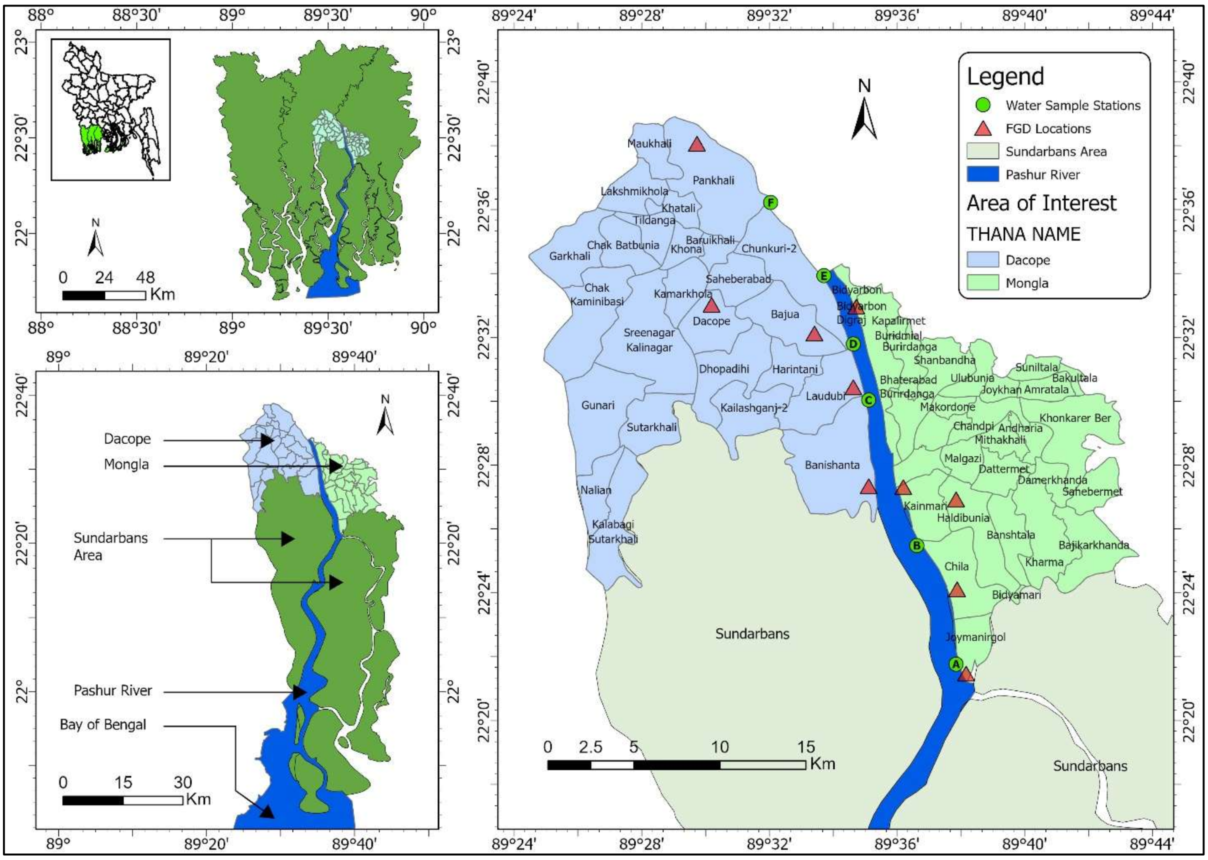

Figure 1. Study area and data collection sites. Dacope and Mongla are separated by the river Pashur and are adjacent to the Sundarban mangrove forest. Water sample stations are marked from A to F in the Pashur River

3. MATERIALS AND METHODS

3.1 FGD and KII

Focus Group Discussions (FGD) have been conducted in 10 stations focusing on directly impacted by the Pashur river in Dacope and Mongla thana (Figure 1). Five stations were in Dacope and the same for Mongla. Although most of those areas are fishermen, we have also found businessmen and farmers. Besides, females' participation has also been considered during the surveys and FGD. Total 300 participants were listed during the FGD, 180 in Dacope, of which 110 were males and 70 females, and 120 in Mongla, which included 80 males and 40 females. The sociodemographic characteristics that were essential to consider while doing a socioeconomic analysis of climate change include the age of and level of maximum longevity, number of family members, highest educational levels of respondents, if and how much money they had in debt, whether their drinking water is not saline, the water that is used for washing, whether the amount of water used for washing has grown over the years if there are new employment opportunities for the people, if they have acne or any new zits and at what age did this start to occur, and where they would migrate if they had the chance, their willingness to change their occupation and the reasons behind them. Five Key Informant Interviews (KIIs) to get the expert's view on the issues related to water quality were conducted where 3 KIIs were

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conducted in Dacope and two in Mongla. The KII participants in this study included upazila health officers, NGO workers and local government representatives of those areas. We tried to get the suggestions to overcome the problems encountered by the community people for degraded water quality and seek policy recommendations from them. There were groups of fishermen, farmers, businessmen, and laborers. Table 1 summarizes the key logistical details of each FGD and KII session.

Table 1. Logistical Summary of FGDs and KIIs

Method	Date	Location	No. of Participants	Facilitator	Notes
FGD	5 Nov. 2023	Dacope Community Center	30 (18F, 12M; ages 20–50)	Researcher of NOAMI	Diverse livelihoods; fishing focus
FGD	7 Nov. 2023	Mongla Village Hall	30 (16F, 14M; ages 18–45)	Researcher of NOAMI	Agricultural and fishing backgrounds
FGD	10 Nov. 2023	Dacope Fishermen's Association	30 (10F, 20M; ages 25–60)	Researcher of NOAMI	Fishing livelihoods; economic challenges discussed
FGD	12 Nov. 2023	Mongla Community Center	30 (15F, 15M; ages 18–50)	Researcher of NOAMI	Impact of climate change on farming
KII (3)	15 Nov. 2023	Dacope Parliament Office	3	Researcher of NOAMI	Insights from local leaders on community resilience
KII (2)	17 Nov. 2023	Mongla Municipal Office	2	Researcher of NOAMI	Discussion on policy and governance implications

FGDs were conducted in accessible, community-centered venues to maximize participation and inclusivity. For example, the Dacope Community Center provided a welcoming environment that encouraged open discussion, while the centrally located Mongla Village Hall ensured representation from varied demographic and livelihood groups. Each FGD was composed with attention to gender balance, age diversity, and occupational variety, enabling a broad spectrum of experiences and perspectives to emerge.

3.2 In-Situ Water Quality

River water quality has been collected (n = 18) in situ with the multi-parameter (BLE-C600) during the winter season (November) at high tides in 2023. Temperature, salinity, pH, total dissolved solids (TDS), and Electrical conductivity (EC) have been recorded. All data has been recorded thrice and averaged to get the most corrected value from each station. Degree Celsius for temperature, PSU for salinity, no unit of pH, mg/l for TDS, and micro-Siemens per centimeter for EC have been used as the units of respective parameters.

4. RESULTS

4.1 Water Quality

Based on the in-situ data collected (Figure 2-a), it was observed that the water temperature was high at stations A, D, and F (Figure 2-a). The highest recorded temperature was 28.9°C, while the lowest temperature was 28.5°C. Although there were some fluctuations between the highest and lowest temperatures, they were not significant. Therefore, it can be claimed that the water temperatures at the remaining six stations were relatively similar. The salinity levels of six stations exhibited significant variability, with station B registering the highest salinity range at 18.9 PSU (Figure 2-b). This observation corresponded with the lowest temperature in the region. Conversely, station C showed the lowest salinity reading at 8.6 PSU. Stations E and F exhibited salinity levels that were near the highest range. The pH values obtained from in-situ data exhibited a closely grouped range, with a variance between 6.8 and 8.48, indicating a near-neutral pH scale (Figure 2-c). The highest pH value of 8.48 was observed at station F. In contrast, the lowest pH value of 6.8 was recorded at station A. Notably, stations E and F demonstrated alkaline pH values, falling within the alkaline zone of the pH scale. The measurement of total dissolved solids (TDS) is a crucial parameter in many environmental studies. According to the in-situ data, the highest recorded TDS was 11710 mg/l (Figure 2-d). Station F exhibited the highest TDS range, while station A demonstrated the lowest range at 6040 mg/l. However, there was little variation in the TDS values of stations A-D. In contrast, fluctuations in TDS measurements were observed at stations E and F. It is worth noting that the TDS concentration in water is a significant factor in determining its suitability for various purposes. High TDS concentrations may indicate the presence of undesirable substances, rendering the water unsuitable for consumption or industrial use. Therefore, accurate TDS measurements are essential in ensuring the safety and quality of water resources. According to the in-situ data, it has been ascertained that Stations E and F have recorded the highest Electric Conductivity (EC) levels. Station D, on the other hand, has been found to exhibit the third-highest EC level. The highest EC level was observed as 14770 µS/cm, while the next highest level was recorded at 13880 µS/cm (Figure 2-e). Conversely, the lowest EC level was noted at Station A, measuring 12030 µS/cm. Table 2 presents descriptive statistics for water quality parameters, including temperature, salinity, pH, TDS, and electrical conductivity (EC), alongside reference mean values. The recorded mean temperature (28.78°C) shows minimal variation, while salinity (14.38 ppt) and TDS (8938.33 mg/L) exhibit moderate to high variability. pH averages at 7.76, indicating slightly alkaline conditions, and EC averages 14356.67 µS/cm, both lower than their respective reference values.

4.2 Socioeconomic Characteristics and Conditions

Both regions have a significant proportion of their population in the productive age group (18-39 years), with 64 individuals in Dacope and 65 in Mongla. However, Dacope has a higher number of individuals over 60 years (42) compared to Mongla (11), which may indicate a higher dependency ratio and potential challenges in supporting elderly populations, especially in the face of economic and environmental stressors (Figure 3). Also, the possibility of higher mortality at an early age in Mongla cannot be denied as the number of aged people can be seen in very low portion.

The education levels in both regions show a concentration of individuals with education up to Class 10 (Figure 4). In Dacope, 75 family members have education up to Class 10, and in Mongla, this number is 62. There is a noticeable drop-off at higher education levels, with only

2 and 3 family members in Dacope and Mongla respectively having passed HSC. This indicates limited access to higher education opportunities. This gap in education could impact the ability of these communities to adapt to changing economic and environmental conditions effectively.

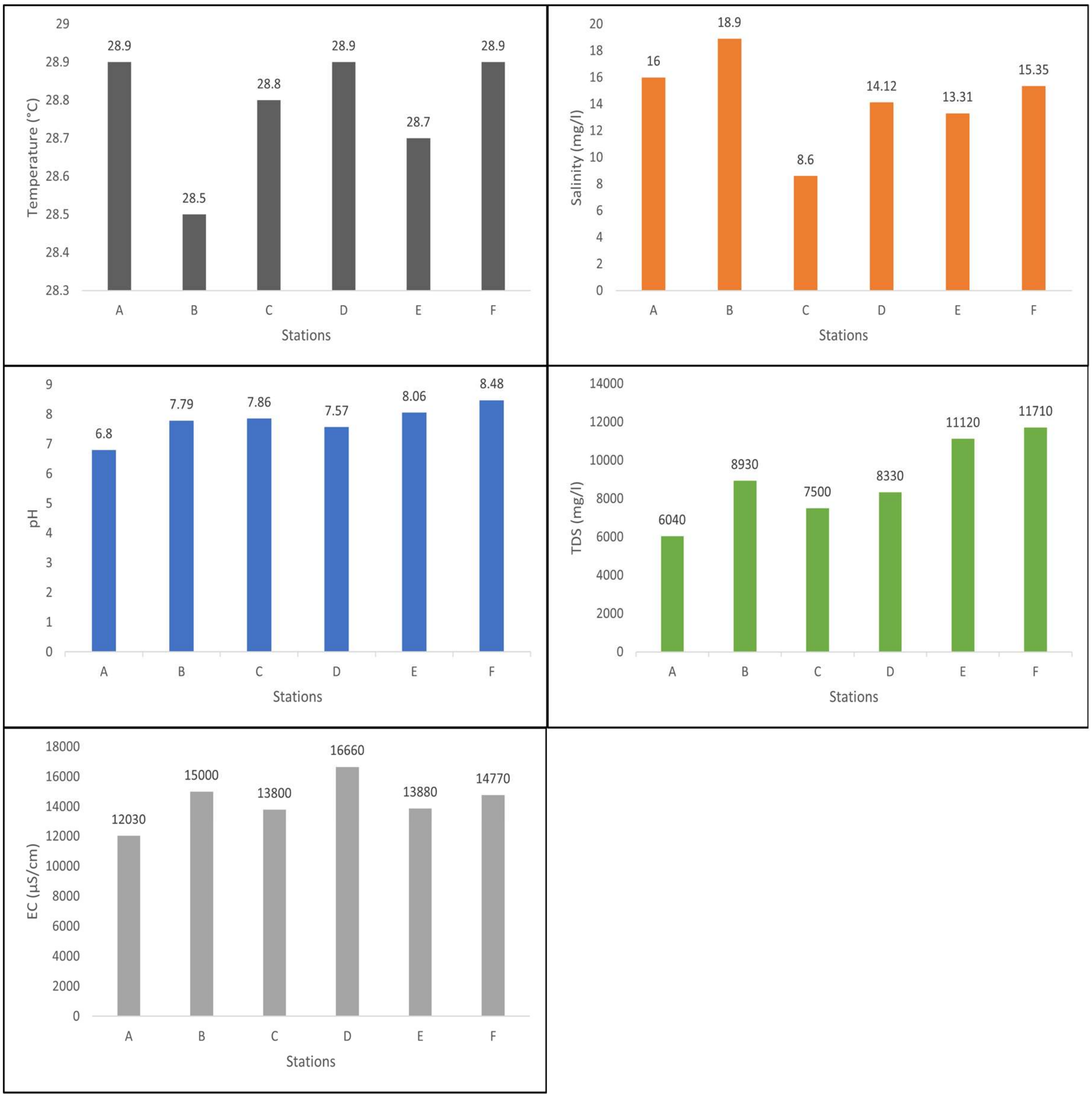

Figure 1. Temperature (a), Salinity (b), pH (c), Total Dissolved Solids (d), and Electrical Conductivity (e) variations among the in-situ stations

Table 2. Descriptive statistics of the observed water quality data (n = 18)

Parameter	Mean	Std Dev	Min	25%	Median	75%	Max	Ref. Mean Value	Ref.
Temp. (°C)	28.78	0.16	28.5	28.73	28.85	28.9	28.9	23.57	(Sowrav et. al., 2023)
Salinity	14.38	3.42	8.6	13.51	14.74	15.84	18.9	20.21	
pH	7.76	0.56	6.8	7.63	7.83	8.01	8.48	8.03	
TDS (mg/L)	8938.33	2157.83	6040	7707.5	8630	10572.5	11710	16090	
EC (µS/cm)	14356.67	1538.87	12030	13820	14325	14942.5	16660	32170	

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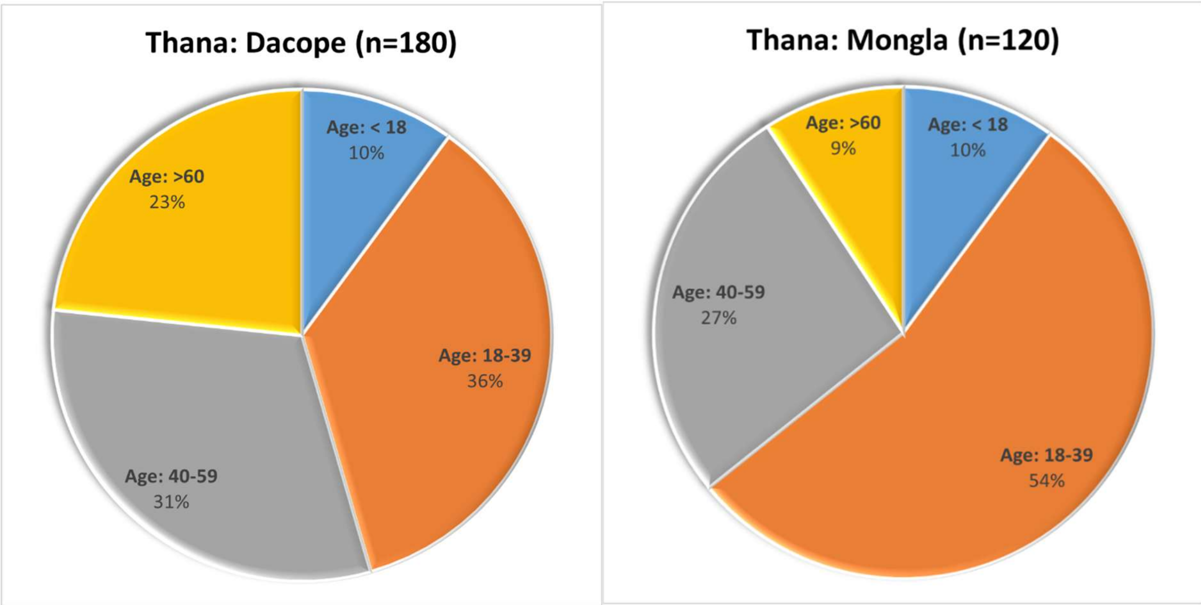

Figure 3. Age distribution of Focus Group Discussion (FGD) participants in Dacope (n=180) and Mongla (n=120)

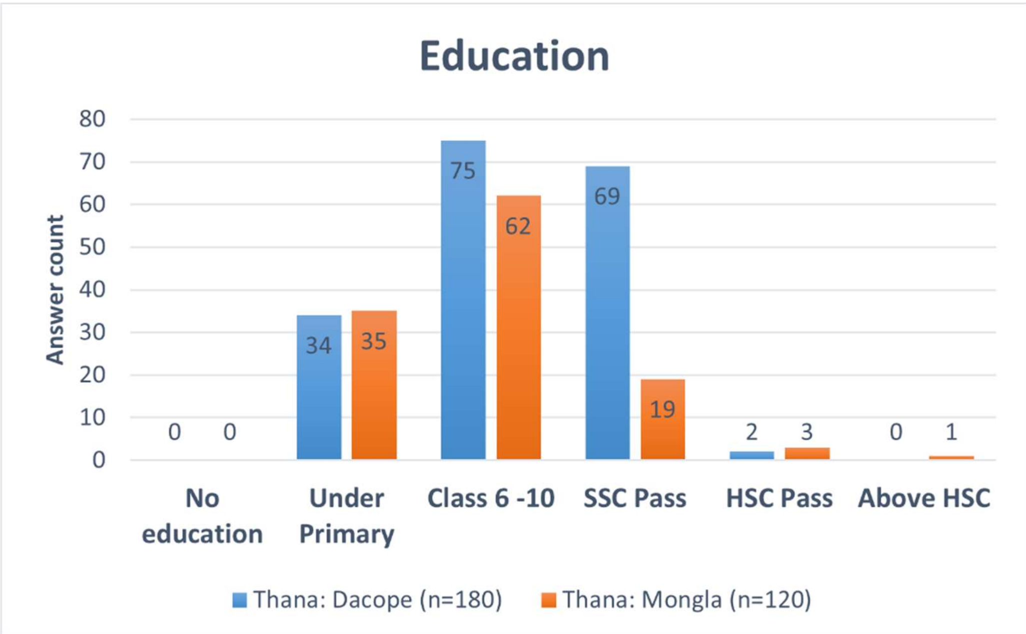

Figure 4. Education status (No Education, Under Primary, Class 6-10, SSC Pass, HSC Pass, Above HSC) comparison between target sites of respondents

In Dacope, larger family sizes (6-8 members and >8 members) are more common, with 95 and 55 families respectively. In Mongla, smaller family sizes (3-5 members) are predominant, with 65 families falling into this category (Figure 5). Larger family sizes could imply higher dependency ratios, which can strain resources and complicate economic resilience in the face of environmental challenges.

The data from FGD indicate a reliance on various water sources for different household activities in both Mongla and Dacope (Figure 6). Freshwater is predominantly used for drinking and cooking in both areas. In Mongla, 78 families use saline water heavily for household washing, while 68 use brackish water for cooking, which is very concerning in terms of health issues. In Dacope, brackish water is more commonly used for household washing (95 families) and bathing (79 families). Freshwater is used by 135 family members for drinking and cooking. This highlights the adaptive strategies of coastal communities in managing water resources based on availability and quality.

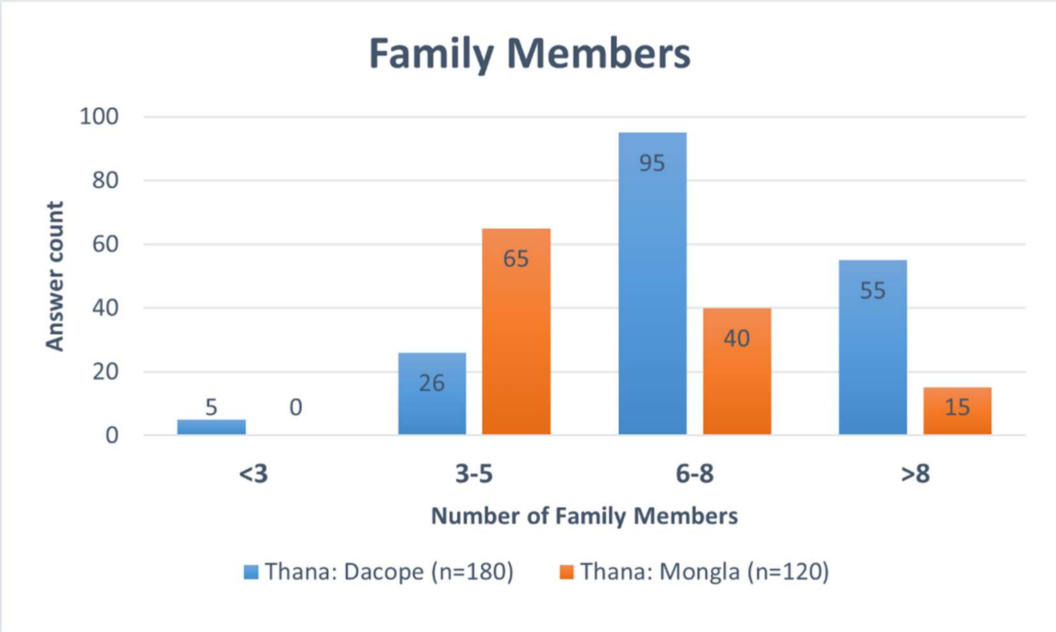

Figure 5. Family size demographic categories (<3, 3-5, 6-8, >8) of the respondent in study area

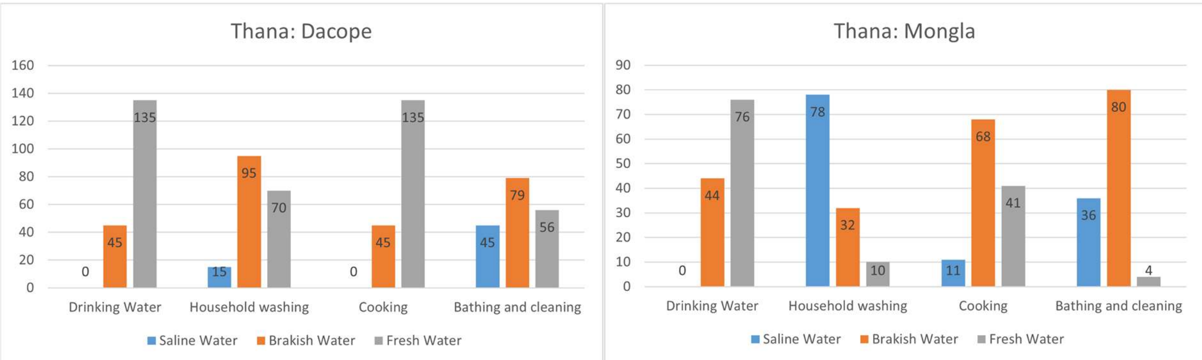

Figure 6. Different water types (saline water, brakish water, fresh water) used by the locals for different usage (drinking, household, cooking, bathing and cleaning) in target areas

In terms of economic condition, the high number of loan recipients in both regions indicates a significant dependence on financial aid to sustain livelihoods. In Dacope, 155 out of 180 respondents have taken loans, while in Mongla, 115 out of 120 respondents have taken loans (Figure 7). This high uptake of loans (86% in Dacope and 96% in Mongla) could be due to economic instability caused by environmental challenges, necessitating external financial support for recovery and development. Instead of solely focusing on the role of loans as a reaction to environmental hardship, it is crucial to view these loans as a sign of financial inclusion, which enables individuals to participate in economic activities and improve their livelihoods. In many developing countries, access to credit is an important means of overcoming economic barriers, and its availability can have a significant positive impact on households' ability to recover from crises and invest in sustainable development.

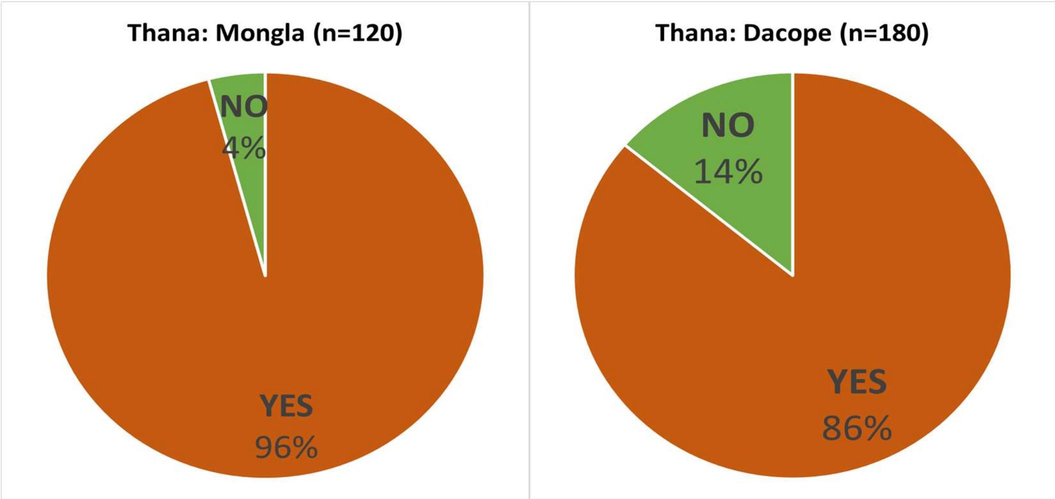

Figure 7. Loan dependency percentage among the Focus Group Discussion (FGD) participants of Mongla (n=120) and Dacope (n=180)

The coastal regions of Dacope and Mongla in Bangladesh are particularly vulnerable to climate change, with significant socioeconomic implications stemming from the quality of river water. This case study delves into various socioeconomic aspects influenced by river water quality, including income trends, skin disease prevalence, climate literacy, and migration intentions (Table 3).

Table 3. Socioeconomic conditions related to climate change (Income, Skin disease, Climate literacy rate, and migration) in both Dacope and Mongla region

Subject	**Dacope (n=180)**	**Mongla (n = 120)**
	Income	
Increasing	17%	32%
Decreasing	78%	65%
Stable	05%	03%
	Skin Disease	
Skin Problem	67%	73%
From Age	30-45	27-37
	Climate Literacy	
Know about climate change	25%	27%
Know about sea level rise	5%	4%
	Migration	
Want to locally migrate	57%	92%
Want to change profession	82%	78%

Income Trends in Dacope, 78% of the population reports a decline in income, with only 17% experiencing an increase and 5% maintaining stable earnings. In contrast, Mongla shows a slightly more optimistic picture, with 32% of individuals reporting increased income, 65% experiencing a decrease, and a mere 3% seeing stability. Participants did not attribute these declines to a specific event like COVID-19, but rather to a prolonged deterioration of environmental conditions, especially increased salinity and the loss of cultivable land and fish diversity. These statistics highlight the economic fragility in these regions, largely attributable to the declining river water quality. In Dacope, those who cultivated shrimp could earn only 150 – 200 BDT per day, but it was unfeasible to continue this for a long time because it was not widely practiced till now. Some farmers or fishermen may work as day laborers, earning 750 – 800 BDT daily. Still, in the lean period, it becomes tough for them to get any harvesting or fishing-related jobs. A female shopkeeper said:

"Due to the cyclone, the jute ceiling of my shop was blown away, and the shop's goods were swept away in the water. The government has given me part of the leased land from where I had one and a half acres of land, but due to the low water level, there is still no cultivation there." (Female, 42, FGD with women in Dacope)

In Mongla, there were insufficient sluice gates, so stagnant water remained due to barrages. Still, where there were sluice gates and culverts for water movement, there was no inundation, with most of the saline water receding within two days. All those places where saline water had accumulated could not be cultivated later due to salinity, making farming difficult in that area. Local farmers informed us that they have not yet cultivated salinity-tolerant rice varieties. They were utterly dependent on freshwater for agriculture. In this case, they use rainwater and river water for agricultural purposes, so they must wait until the monsoon season for crop production. One local farmer said:

"Except for the rainy season, our farming land remains unusable the rest of the time. When the salt water accumulates, we can farm some unconventional fish varieties, but it cannot be continued for more than 15 days. Only those with their own enclosures or fish projects can remove the salty water during this period, but fish farming was impossible in open areas during that time." (Male, 47, FGD with farmers in Mongla)

The prevalence of skin diseases is alarmingly high in both regions, with 67% of Dacope's population and 73% of Mongla's population affected. The primary age group suffering from these conditions in Dacope is 30-45 years, whereas in Mongla, it is 27-37 years (Table 3). This high incidence of skin diseases can be linked to the deteriorating quality of river water, which residents rely on for drinking, bathing, and other daily needs. Contaminated water, laden with high salinity and pollutants, leads to dermatological issues, exacerbating the health and well-being of these coastal communities. The slightly higher prevalence in Mongla may be indicative of worse water quality or more direct exposure to contaminated water sources.

However, people in Dacope and Mongla had no problem with the drinking water there. All the people in the area drank water from deep tube wells. The local people perceived salinity as quite a normal issue in their lives. Researchers outside the area using deep tube well water found the presence of heavy salt there, which made it unsuitable for drinking, but this salinity seemed normal to the local respondents.

Climate literacy is relatively low in both regions, with only 25% of Dacope's population and 27% of Mongla's population being aware of climate change. Knowledge about sea level rise is even more scarce, with only 5% of Dacope and 4% of Mongla being informed (Table 3). Most people in both areas did not know if climate change causes sea level rise. Some respondents in Dacope reported that they learned about climate change through television news. Some families there had access to the Internet, which allowed them to keep up with national and international climate and environmental news. Respondents in Mongla stated that they observed the breaking of the seashore. The seawater was coming closer to the locality day by day, and gradually, all the buildings and trees near the seashore had disappeared.

Mongla Fishermen depended entirely on their local knowledge and identify the direction of storms to avoid danger. Using indigenous knowledge, the local people tried to predict the changes in weather by observing east wind, south wind, and monsoon wind. This lack of awareness is concerning, given the direct impact of climate change on their livelihoods and living conditions. One of them said:

"Most of the time, we do not get any timely warning, or if we got any, most do not understand those. We believe a strong correlation exists between their area's tides and easterly winds. The water rises greatly if there is an east wind and a tide in the river." (Male, 54, FGD with fishermen)

Migration intentions are notably high in both regions, reflecting the severe socioeconomic distress caused by environmental degradation. In Dacope, 57% of the population expresses a desire to migrate locally, while 82% consider changing their profession (Table 3). The primary reasons for migration include insecurity due to disasters and declining agricultural productivity due to increased salinity. Similarly, in Mongla, 92% of the population wants to migrate locally, and 78% are looking to change their profession.

When people respondents from both areas were asked about their adaptation strategies, they enlisted some of the activities (Table 4). People of Dacope Upazila were shifting from rice cultivation to other crops. So, reducing the pressure solely on rice cultivation served as a coping strategy for farmers in that area. Apart from paddy, people cultivated catfish, sunflowers, almonds, corn, and pepper. The locals agreed they had less income than the previous year, so they had to work a lot of time and look for diverse work to cover the financial losses. They knew a little about what kind of farming could be done in saline land or what type of fish could be cultivated in the same water. Moreover, they considered it risky to take the initiative to grow new crops or fish in saline water since they needed more capital. Some people were reluctant to borrow money entirely from NGOs as they believed that if they accepted funds from the NGO, they would be unable to pay the loans with interest. The business might benefit from the loan in the short term, but it could shatter if any disaster occurs, and they fail to repay it. So, the thought of microcredit was not very popular among the salinity-affected area's workers. One fisherman said:

"Telapia, Rui-Katla and shrimp can be cultivated in salt water, but due to a lack of capital, I cannot take the initiative of cultivation." (Male, 35, FGD with fishermen in Dacope)

In Mongla, the seeds provided to farmers of that area by the Bangladesh Agricultural Development Corporation (BADC) were insufficient. Local farmers said no government or private institution provided them with a solution to withstand salinity. A local farmer further said:

"During Chaitra-Baishakh, as it is the dry season, no freshwater flows from upstream rivers. The salinity level reaches a peak at 12 – 16 dS/m. This amount of salt rots the roots of any plant, so no cultivation is possible." (Male, 32, FGD with farmers in Mongla)

Table 4. Respondents' opinions from FGD and KII on different criteria in Dacope and Mongla

S.N.	Criteria	Results	
		Dacope	Mongla
1	Socio-economic consequences	• Lack of stable income sources • Become unemployed when soil and water salinity increase • Disinclination towards shrimp cultivation • Increased cases of skin diseases • Reduced production of usual crops and fish due to saline soil and water • Drinking salty water from tube wells	• Lack of stable income sources • More prevalent skin diseases among young women and adolescent girls • Insufficient number of sluice gate • Crop production hampered after recession of saline water. • Must wait till monsoon season to use freshwater for crop production • Drinking salty water from tube wells
2	Climate literacy	• Did not know that climate change causes sea level rise • Heard about climate change from TV news and social media	• Did not know that climate change causes sea level rise • Understanding of seashore declination from observation • Depends mostly on indigenous knowledge for weather prediction
3	Adaptation Strategies	• Enhanced loan taking • Local migration • Reasons for migration: insecurity to disasters • Crop diversification • No available salinity-tolerant crop variety • Lack of knowledge about salinity-tolerant crops and fishes • Lack of affordable microcredit • Changing profession due to less crop due to salinity and less fish in river	• Insufficient salinity-tolerant seed given by the government • Enhanced loan taking • Temporary and permanent migration • Local migration • Reasons for migration: salinity, insecurity to disasters • Practice of personal fish projects in the saline water • Changing profession due to no crop, less economic activities, high degradation of fishes in river.

5. DISCUSSION

The case study of Dacope and Mongla provides a comprehensive overview of the profound impact of river water quality on the socioeconomic characteristics of climate-vulnerable coastal communities. The significant income decline, high prevalence of skin diseases, low climate literacy, and strong migration intentions paint a picture of communities in distress.

The results of the in-situ water quality assessment indicate a relatively stable thermal environment across the sampling stations, with temperatures ranging from 28.5°C to 28.9°C, which aligns with findings from (Sowrav et al., 2023), who reported similar temperature ranges in comparable aquatic ecosystems. Salinity levels exhibited significant variability, with station B recording the highest salinity at 18.9 PSU, which is consistent with the observations of (Sawestri et al., 2021) regarding the influence of salinity on aquatic biodiversity. The pH values, ranging from 6.8 to 8.48, suggest a predominantly near-neutral to slightly alkaline environment, which is crucial for maintaining aquatic life, as noted by (Wu et al., 2022). Furthermore, the TDS and EC measurements indicate potential concerns regarding water quality, particularly at stations E and F, where elevated levels could signal pollution or high mineral content, corroborating the findings of on the implications of TDS for water resource management (Pambudi et al., 2021).

The education system in the visited areas is severely hindered by inadequate infrastructure and a lack of educational centers, which has resulted in many individuals being unable to complete their primary education. This situation is alarming, as education is a fundamental right essential for personal and societal development. Infrastructure significantly impacts educational outcomes, particularly for vulnerable populations (Ahawo et al., 2015). Moreover, financial barriers to education further exacerbate this issue, as many families struggle to afford educational costs, perpetuating a cycle of poverty. This observation is supported by the work of (Djankov et al., 2002), which highlights the strong correlation between infrastructure availability and poverty levels. The reliance on diverse water sources for daily activities underscores the critical role of water quality in these regions, as poor water quality can adversely affect health and, consequently, educational attainment (Merrill et al., 2018). Furthermore, demographic pressures, such as family size and age distribution, can influence the resilience and adaptive capacity of these communities, necessitating a multifaceted approach to improve both educational access and water quality.

Salinity intrusion and reduced fish populations have diminished agricultural productivity and fisheries, leading to reduced income for residents (R. Islam et al., 2023). Though shrimp farming is beneficial for coastal communities (Ray et al., 2021) as they face salinity intrusion due to climate change, this research found that respondents in Dacope could not practice shrimp cultivation largely as it needs more capital and investment which the people in that area are unable to afford (R. Islam et al., 2023). Additionally, marginal farmers cannot pursue this profession due to conflict over land and water resources with wealthy farmers (Afroz et al., 2017). Dacope and Mongla, both regions are victims of natural calamities such as cyclones, storm surges, salinity intrusion etc. and at this time they cannot continue their conventional profession resulting in income declination. This finding is similar to studies stating that escalating cyclones and floods impair fishing equipment and decrease fish yields (Rayhan et al., 2022), cessation of fishing activities, low pricing of fish, and the scarcity of purchasers (Uddin et al., 2022), resulting in reduced revenue. This situation leads to financial instability and dependence on loans (Mohiuddin & Nowreen, 2024). The disparity between the two regions suggests that Mongla might have had slightly better access to alternative income sources or more resilient economic structures, although both areas face significant economic challenges.

Our finding corresponds to studies by (Bhowmik et al., 2023) revealed that coastal aquaculture in Bangladesh is significantly dependent on freshwater, which is susceptible to salinity fluctuations, impacting agricultural and fishing operations, necessitating integrated water management measures for resilience (S. H. Rahman & Barua, 2023). In coastal Bangladesh, inadequate sluice gates cause drainage congestion, high soil salinity, and inefficient water regulation, extreme weather conditions and higher amounts of salinity negatively affect agriculture and fisheries productivity (M. A. Rahman et al., 2022; Yadav et al., 2020). (Nowreen et al., 2014) suggested that the sluice gates in Bangladesh's coastal areas are insufficient owing to a lack of comprehension of hydro-morphological features, poor upkeep and operation, and neglect of social and cultural considerations. This scenario has been found relevant in Mongla by this study.

In line with our studies, several studies were conducted in coastal areas which found that polluted water was responsible for skin diseases along with many chronic illnesses, e.g., arsenicosis, diarrhea, and pneumonia (Ashrafuzzaman et al., 2023; Nasreen et al., 2023). This research found that people of the reproductive age group were highly susceptible to skin diseases as negative consequences of degraded water quality. This finding is similar to other studies (Lin et al., 2022) with a special focus on coastal vulnerable women as they use saline water for menstrual hygiene and sanitation (Sinha et al., 2024). The respondents in the study areas were ignorant of the salinity in the drinking water, so they were not aware of the adverse health effects (Chakraborty et al., 2019) of this and so failed to take any initiative for drinking water purification and source preservation.

A significant number of households fail to recognize their water as hazardous, although heightened pollution levels highlight a deficiency in climate literacy highlighted by (Benneyworth et al., 2016). Effective adaptation and response to environmental changes are obstructed by an absence of climate literacy in locales which coincides with the study by Rahman and Obaydullah (2020). Developing resilient strategies and locally-led adaptations to address ongoing and future impacts necessitates increased educational initiatives and community outreach programs (M. Islam & Paul, 2018; B. Roy et al., 2022). Respondents in the study areas were hardly aware of climate change and its impact such as sea level rise leading to their daily use of polluted water without purification and hindering sustainable water management strategies.

This paper aligns with the result that communities implement a variety of adaptation strategies, such as the application of indigenous knowledge, the modification of sowing timelines, and diversified farming (Amin et al., 2021; Sultana & Luetz, 2022). The local population has shifted from being fishermen to other professions due to the freshwater and instability. The dwindling of fish and its pollution have made fishing less profitable, making it difficult for fishermen to sustain their families. As a result, many have turned to day labor or farming to support their families (Rayhan et al., 2022). People in both areas had limited knowledge about climate-resistant crop varieties and education, size of farms, yearly revenue, creativity, and understanding of cultivating rice exhibited a substantial and positive correlation with the adoption of saline and flood-tolerant crops ("Adoption of Salt Tolerant Variety in the Coastal Areas of Bangladesh," 2014). (M. A. Islam et al., 2022) found that the diverse viewpoints of farmers about salinity and adaptation choices in coastal Bangladesh underscore the importance of localized policy measures and prioritized research to ensure long-term agricultural advancement. Nevertheless, under these efforts, obstacles such as recurrent extreme weather events, insufficient infrastructure, and limited financial resources persist in impeding successful shifts in livelihoods (A. Roy & Basu, 2020).

However, in contrast to some research, the respondents in the study locations fell behind in adopting adaptation methods such as diversifying revenue sources, rainwater collection, and water desalination (M. O. Rahman et al., 2022; Ullah & Rahman, 2014). Several studies (Barua & Saha, 2024; Sarker et al., 2023) have also identified internal migration as an adaptation strategy stating residents have occasionally relocated to urban areas for employment during adverse conditions, as a result of climate-induced disasters. The main drivers of migration were salinity, insecurity from disasters, and economic hardships due to the high degradation of fish populations and loss of crops in this study (Naz et al., 2024). explored that permanent migration might happen in the aftermath of extreme conditions such as cyclones, while seasonal and transient movement is frequently employed to address slow-onset consequences such as the increase in salinity and temperatures. Recent advancements in semi-automated water quality assessment illustrate how machine learning can enhance spatial-temporal understanding of water quality parameters in complex coastal ecosystems. For example, Sowrav et al. (2025) developed a semi-automated technique using machine learning for surface water quality analysis in the Sundarbans, demonstrating improved efficiency and predictive capacity for multiple water quality indicators in a highly dynamic estuarine environment.

This paper, therefore, is comprehensive in a sense as the challenges and requirements for adaptation of coastal communities have been identified. The study integrates social and economic factors, including the limitations in fisheries or agricultural productivity, public health concerns about water contamination from home sewage systems, and small-scale farmers' financial vulnerabilities.

KIIs highlighted a number of serious challenges and systemic responses required to address climate associated water and livelihood vulnerability in coastal Bangladesh. Respondents stressed the need for investment in modern coastal water management infrastructure to address siltation of drainage, congestion, as well as salinity intrusion due to poorly maintained sluice gates. Key policy instruments were the Bangladesh Delta Plan 2100 and National Water Policy; Bangladesh Water Development Board (BWDB) and Local Government Engineering Department (LGED) have a central role in reversing the pressure. The interviews also indicated that climate-proofing in agriculture and fisheries needed to be extended to stem declining productivity because of salinity and climate stress. In this respect, the Climate Change Strategy,

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Agricultural Extension Policy, the Department of Agricultural Extension (DAE) and other institutions including Non-Governmental Organizations (NGOs) were mentioned. Lack of community awareness on the sustainability of the water resources, and climate change became another issue to be addressed through public awareness programs under the National Environmental Policy. Participants called for sustainable fisheries management to avoid depletion of stocks, particularly following cyclones. The promotion of Integrated Water Resource Management (IWRM) featured as a means to avoid over-extraction and associated salinity impacts. Finally, the interviews highlighted the importance of financial support mechanisms to support vulnerable farmers to adapt, for example, wherein they referred to Bangladesh Bank's green financing policies and microfinance mechanisms. The paper also highlights the necessity for locally-led adaptation and resilience building, focusing on community climate literacy, infrastructure, and tailored financial support (Table 5). This layered model provides depth and, therefore, more targeted recommendations and policy relevance to the benefit of both policymakers on one hand, and practitioners for that matter.

Table 5. Recommendations and Instruments for targeted problems related to water quality

Recommendations	Targeted Problems	Related Instruments	Responsible authority
Invest in modern coastal water management infrastructure	Drainage congestion and salinity intrusion from poor upkeep of sluice gates	- Bangladesh Delta Plan 2100 (GoB, 2018a) - National Water Policy (1999) (GoB, 1999) - Coastal Development Strategy (2006) (GoB, 2006)	- Bangladesh Water Development Board (BWDB) - Local Government Engineering Department (LGED)
Expand climate-proof farming and livelihoods	Falls in agricultural productivity and fisheries because of salinity intrusion and climate change impacts	- Climate Change Strategy and Action Plan (BCCSAP, 2009) - Agricultural Extension Policy (2020) (GoB, 2020)	- Department of Agricultural Extension (DAE) Department of Fisheries (DoF) - NGOs
Strengthening Community Climate Literacy and Awareness	No understanding of the impact for climate change and sustainable water use in vulnerable areas	- National Environmental Policy (2018) (GoB, 2018b) - Bangladesh Delta Plan 2100 (GoB, 2018a)	- Ministry of Education - NGOs and CSOs
Manage fisheries responsibly and sustainably.	Fish populations decrease and ruin fish stocks in cyclone-affected regions	- Bangladesh Fisheries Policy (1998) (GoB, 1998)	- Ministry of Fisheries and Livestock (MoFL) - Bangladesh Fisheries Research Institute (BFRI)
Promote Integrated Water Resource Management (IWRM)	Over-extraction of water resources which in turn is causing salinity, impacting both crops and drinking water	- National IWRM Plan (under Water Act 2013) (GoB, 2013) - National Water Policy (1999) (GoB, 1999)	- Bangladesh Water Development Board (BWDB) - Department of Environment (DoE)
Extend Financial Support for Climate Adaptation	Limited capital for farmers to shift towards climate-resilient crops or alternative livelihoods	- Bangladesh Bank's Green Banking Policy (2011) (Bangladesh Bank, 2011) - Microfinance Regulatory Authority Act (2006) (GoB, 2006)	- Bangladesh Bank - MFIs and NGOs

Beyond reaffirming existing trends, this study offers novel insights by providing granular, localized data on the direct correlation between specific water quality degradation (e.g., high salinity, elevated EC) and its nuanced socioeconomic consequences within Dacope and Mongla. Our findings uniquely highlight the pervasive health burden of skin diseases (68% prevalence) directly linked to water quality, the significant economic fragility reflected in high migration intentions (92% in Mongla) and loan dependency, and critically, the widespread lack of climate literacy and perceived normalcy of salinity among residents. These empirical observations underscore the inadequacy of current generalized approaches and provide precise intervention points. For instance, the data necessitate targeted public health campaigns on water safety, microfinance initiatives to enable investment in salt-tolerant livelihoods, and localized climate education programs that address specific community perceptions and barriers to adaptation. This study thus provides actionable, evidence-based policy implications for water management, agricultural resilience, and public health strategies tailored to the unique vulnerabilities of these coastal communities.

6. CONCLUSION

This study demonstrates that deteriorating river water quality in Dacope and Mongla is not merely an environmental concern but a structural driver of livelihood insecurity, health vulnerability, and limited adaptive capacity in coastal Bangladesh. Rather than reiterating measured parameters, the findings underscore how persistent salinity exposure and degraded water conditions shape everyday decisions related to occupation, migration, health behavior, and climate awareness.

From a policy perspective, the results point to three priority intervention pathways. First, water management interventions should focus on improving local-scale control of salinity intrusion through the rehabilitation and climate-proofing of sluice gates, drainage systems, and freshwater access points. Such measures are essential to stabilize both agricultural productivity and household water use. Second, livelihood diversification strategies must move beyond short-term coping mechanisms by enabling access to salt-tolerant crops, adaptive aquaculture practices, and affordable financial support that allows small-scale farmers and fishers to invest without increasing debt vulnerability. Third, climate education and literacy programs should be locally tailored, addressing the widespread normalization of salinity and limited awareness of long-term health and livelihood risks associated with poor water quality.

Strengthening coordination among local government institutions, extension services, NGOs, and community organizations will be critical for translating these pathways into effective action. By aligning water governance, livelihood planning, and climate education, the findings offer a practical framework to reduce health risks, limit forced migration, and enhance long-term resilience in climate-vulnerable coastal communities. Future research should extend this work by quantifying economic losses across seasons and examining gender-differentiated health impacts to further inform targeted adaptation policies.

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CONFLICTS OF INTEREST

The authors have no conflict of interest.

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