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REDUCTION OF FISH PRODUCTION IN HAKALUKI HAOR CAUSED BY CLIMATIC AND ANTHROPOGENIC FACTORS

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Abstract

A study was conducted to examine the various factors influencing the decline in fish production in the Hakaluki Haor wetland ecosystem in northeast Bangladesh, aiming to investigate the impacts of both climatic and anthropogenic factors on fish production in the area. Nowadays, this wetland is increasingly impacted by climate change, which poses significant challenges to fish production and sustainability. The primary data were collected through a face-to-face questionnaire survey (n = 150) with fishers, focus group discussion (n =15), and key informant interviews (n = 10). The majority of the fishers were middle-aged group (31-50 year), whereas 41% had primary level (schooling year 5) of education and 48% were highly experienced fishermen (≤16 years). Stakeholder perceptions of human activities, including overfishing (52%), discard of non-target species (23%), use of destructive fishing gear (67%), beel drying (47%), habitat destruction (48%), water pollution (23%), migration route changes (30%) and agricultural intensification (45%), have been identified to reduce fish production. Additionally, the study revealed that climate change impacts the ecosystem, including temperature fluctuation (57%), erratic rainfall (49%), flood and flash flood (37%), drought (17%), and siltation in beel (37%). Stakeholders perceived these impacts to have significant negative effects on aquatic biodiversity, particularly in terms of habitat destruction and water quality degradation. This study proposes potential solutions to mitigate the impacts of climate changes and man-made factors associated with fish production reduction in the region, such as improved water management practices, diversification of fish species, and the use of climate-resilient fisheries management. Community engagement and government support are highlighted as crucial factors to address the impacts of climate change on fish production in Hakaluki Haor. The findings of this study have important implications for the development of effective management strategies for ensuring sustainable livelihoods for fishers.

Key words: Challenges, climate change, fish production, Hakaluki Haor

Introduction

The fisheries sector plays a vital role in the economy of Bangladesh. It provides employment to a large number of people and contributes significantly to the country's gross domestic product (Alam et al. 2019). Additionally, fish is a major source of protein for the population, and the country is also a major exporter of seafood, providing a significant source of foreign exchange (DoF 2020, Alam et al. 2022). The sector also has a positive impact on the rural economy by providing livelihoods for communities living along the coast and in inland areas. Furthermore, the sector also helps in conserving biodiversity and maintaining the

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ecological balance of the country's waterways. Overall, the fisheries sector is crucial for the socio-economic development of Bangladesh.

Capture fisheries and aquaculture contribute significantly to rural diets and national food security by providing protein-rich food (Alam et al. 2021). Total fish production (2.1 million MT in 2003; 4.6 million MT in 2022) has increased over the years owing to increasing aquaculture production (DoF 2022); however, concomitantly the relative growth of capture fisheries is in decline. The production of capture fisheries from inland and marine sources depends heavily on different open water resources such as rivers, beels[i], floodplains and Haors[ii].

Hakaluki Haor is a seasonal wetland located in the northeast region of Bangladesh. It is an important ecosystem that provides critical ecological and economic services, such as flood control, water storage, and habitat for fish, migratory birds, and other wildlife. The wetland also supports the livelihoods of local community people, who rely on it for fishing, agriculture, and other forms of income. Hakaluki Haor is designated as an ecologically critical area (ECA) and also is considered one of the most valuable wetlands in Bangladesh (DoF 2015). Despite its significance, the wetland faces many threats, including climate change, over-exploitation of resources, and the loss of fish diversity (Haque et al. 2017, Bremer et al. 2018, Aziz et al. 2021, Tikadar et al. 2022). Efforts are being made to protect and conserve Hakaluki Haor, including community-based management, conservation programs, and education initiatives.

Climate change has had a significant impact on Hakaluki Haor, the region is facing increasing temperatures, erratic rainfall patterns, and siltation in beel all of which are contributing to the degradation of the ecosystem and the loss of biodiversity (Aziz et al. 2020). The changes in climate have also had a severe impact on the embryonic development of fishes (Siddique et al. 2022a, Siddique et al. 2022b, Mahalder et al. 2023) as well as the livelihoods of local communities who rely on the wetland for their food, water, and income. This has led to increased poverty, hunger, and other social problems. The situation in Hakaluki Haor highlights the urgent need for action to address the global issue of climate change and its effects on vulnerable communities.

Although fisheries play a crucial role in the economy of Hakaluki Haor region, research in terms of investigating the impacts of climate change in this area is still limited. While a few studies have explored certain aspects such as the decline in fish species diversity, eco-environmental changes in wetland resources, climate change impacts using remote sensing and GIS, and the effects of climate change on livelihoods, a comprehensive understanding of climate change on fish production in Hakaluki Haor is still lacking. Despite the existing studies, the research in terms of the impacts of climate change in the region remains inadequate. Therefore, the present study aims to identify the impacts of climate change on fish production in Hakaluki Haor that may facilitate policy stakeholders in Bangladesh.

Materials and Methods

Site selection

The study areas were Barlekha, Juri, Kulaura Upazila under Moulvibazar district and Fenchuganj, Golapganj Upazila under Sylhet district. The survey was conducted in the actual area of the Hakaluki Haor, which constitute depressed land considerable for more diversified weather impacts on fisheries (Fig. 1). The geographic location of the Haor is latitude 24°35' N to 24°45' N and longitude 92°00' E to 92°08' E. Therefore, the study area was selected due to the position of the Haor and the decline of fish catch.

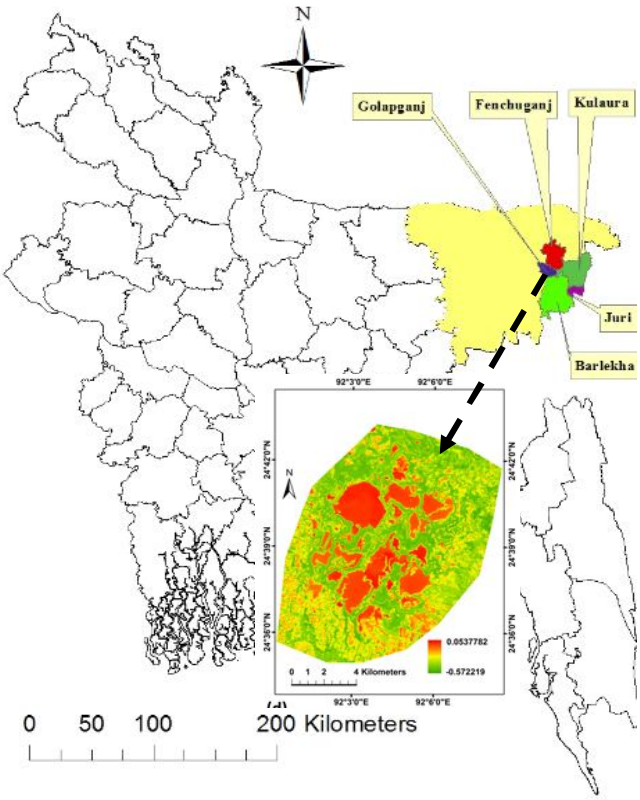

Fig. 1. Map of Bangladesh, showing the study site of Hakaluki Haor.

Data collection

The study in Hakaluki Haor employed multiple data gathering methods, including key-informant interviews (KII), questionnaire interviews, and focus group discussions (FGD), and using these tools together makes such study robust and minimizes the bias (Haque 2007). Key informants, such as local Upazila Fisheries Officers and influential stakeholders were selected based on their expertise and knowledge of the fishing communities. This ensured that the collected information came from individuals with a good understanding of the impacts faced by the fishermen. The study also used Participatory Rural Appraisal (PRA) tools to actively involve local communities and gather diverse perspectives, minimizing bias. Information obtained from different sources, such as key informant interviews, questionnaire responses, and focus group discussions was cross-checked to identify any inconsistencies or discrepancies. Ten KII and Fifteen FGDs were conducted in the study area. Any discrepancies were further investigated and clarified with the participants. In terms of sampling of fishermen, a simple random sampling technique was used to select the sample of 150 fishermen from the study sites of Barlekha, Juri, Kulaura, Fenchuganj, and Golapganj. A sampling frame, which was a list of fishermen in each study site, was created. Each fisherman in the sampling was assigned a unique number, and random number generation was used to select the desired number of fishermen for the study, ensuring that each fisherman had an equal chance of being selected. Overall, the study aimed to overcome bias, enhance data quality, and provide a comprehensive understanding of the reduction of fish production and the impacts of climatic factors on fisheries resources in Hakaluki Haor.

Data analysis

All the data were collected from the study area and entered into the MS Excel sheet, statistical analyses were carried out using the statistical software package MS Excel and SPSS (Statistical Package for the Social Sciences) Version 23 (SPSS 23; SPSS Inc., Chicago, IL, USA). The descriptive statistics, such as mean and range, were produced to discuss the results of the climate change impact on fish production in Hakaluki Haor.

Results and Discussion

Socio-economic status of fisheries in Hakaluki Haor

The socioeconomic status of fishermen in Hakaluki Haor, Bangladesh is likely to be low. This is because fishing is often a livelihood option for marginalized communities, and the region is prone to poverty and food insecurity. Many fishermen in the area may face challenges such as lack of access to education, healthcare, and financial services, as well as limited opportunities for income generation. Climate change and environmental degradation may also have a negative impact on their fishing activities and overall well-being.

A set of socio-economic data including age, education, religion, family status, and occupation was gathered for the surveyed fishermen from all five sites. The majority of the fishers in all of the survey sites were between the ages of 31 and 50, ranging in age from 15 to 65. Also, it was noted that 61% of fishers across all locations had completed primary school, while a minimal number had completed secondary education (Table 1). In terms of religion, there were differing findings among the sites, with Muslim fishermen predominating.

Table 1. Demographic and socioeconomic characteristics of Hakaluki Haor fishermen.

Characteristics	Mean ± standard error	Number of fishermen (n = 150)	Percentage (%)
Age of fishermen			
Young age (15-30)	40.59±0.84	55	37
Middle age (31-50)	(Max: 73,	63	42
Old age (51≥)	Min: 17)	32	21
Education level			
Illiterate (0)	6.38±0.35	53	35
Primary level (1-5)	(Max: 16,	61	41
Secondary (6-10)	Min: 0)	19	13
Higher secondary (11-12)		14	9
Above higher secondary (>12)		3	2
Experience in fishing			
≥ 5	11.18 ±0.95	11	7
6−10	(Max: 42,	30	20
11−15	Min: 2)	37	25
≤16		72	48

Contd.

Occupation			
Fishing	-	88	59
Aquaculture		23	15
Crop farming		15	10
Small business		13	9
Rickshaw/Auto rickshaw		11	7
Household member	6.56±0.13		
Nuclear family		19	13
Medium (5)		97	65
Extended family		34	22
Number of children			
School going children			
Religion			
Muslim	-	97	65
Hindu		50	33
Christian		3	2

The age of the fishers had the greatest impact on their activities, which resulted in a decrease in the variety of fish species in the Haors (Alam et al. 2016). FGDs made it clear that older fishermen tended to catch fish according to their customary methods rather than obeying the rules that the DoF(Department of Fisheries) had recently imposed. Also, older fishermen are frequently illiterate and have a poor understanding of fishing regulations (Haque et al. 2021). The government laws and fish breeding seasons, however, are relatively better known to the younger literate fishermen. Low education may indirectly influence fishermen's indiscriminate fishing tendencies, which reduces the variety of fish species in the Haor. Fishers with more education are more likely to adhere to fishing restrictions than those with less education.

Causes of the reduction of fish production in Hakaluki Haor

Climatic factors

Impact of temperature fluctuation

Temperatures fluctuation was perceived by stakeholders to be a significant problem with a percentage of 57% (Fig. 2). The weather data of Bangladesh Meteorological Department, showed similar trend of gradual rising of temperature (Islam et al. 2018). This suggests that the increase in temperature is a matter of concern for the stakeholders, and they believe it has negative impacts on the aquatic ecosystem. The rise in temperature can lead to changes in the species composition, distribution, and productivity of fish populations. It may also cause the growth of harmful algal blooms, which can lead to fish kills and other problems. Islam et al. (2021) found that rising temperatures have led to changes in fish migration patterns and altered the timing of fish breeding and spawning in Hakaluki Haor. In addition, the warming of water can also result in oxygen depletion and the growth of harmful algae, which can negatively impact fish populations. To address this issue, measures such as the implementation of climate-resilient aquaculture practices and the restoration of natural habitats need to be put in place to ensure the long-term sustainability of fish production

in Hakaluki Haor. Therefore, it is crucial to take appropriate measures to mitigate the effects of rising temperatures on the aquatic ecosystem to ensure the sustainability of the fisheries sector.

Erratic rainfall

Erratic rainfall has been a persistent issue for the Hakaluki Haor wetland ecosystem in Bangladesh, leading to detrimental impacts on the local communities and biodiversity. About 49% of stakeholders agree that erratic rainfall is a serious problem imposed by climate change (Fig. 2). The Haor region receives most of its precipitation during the monsoon season, but the timing and intensity of rainfall have become increasingly unpredictable, leading to prolonged droughts and devastating floods. Analyzing weather data of BMD, Uddin et al. (2013) reported similar pattern of rainfall in the region of Hakaluki Haor. The degradation of the ecosystem has also led to a decline in fish populations, affecting the livelihoods of local communities who depend on the wetland for their food and income. The situation has been exacerbated by anthropogenic factors such as deforestation, land-use change, and climate change (Rahman et al. 2019, Kabir et al. 2020, Islam et al. 2021). Addressing the challenges of erratic rainfall and its impacts on the Hakaluki Haor requires concerted efforts by governments, communities, and civil society organizations to promote sustainable land-use practices and mitigate the effects of climate change. It is important for stakeholders to work together to address this issue and develop adaptive strategies to mitigate the effects of unpredictable rainfall patterns.

Flood and flash flood

Hakaluki Haor, located in the northeastern region of Bangladesh, is prone to flooding and flash flooding due to its topography and heavy rainfall during the monsoon and pre monsoon season. Nearly 37% of the respondents consider flood and flash flood to be a major issue in their region (Fig. 2). Floods in this region occur annually, causing extensive damage to crops, infrastructure, and human lives. In recent years, the severity and frequency of flooding have increased due to climate change and human activities, such as deforestation and land use changes. Flash floods, in particular, pose a significant threat to the region as they occur rapidly and with little warning. In 2017, flash floods in Hakaluki Haor affected over 200,000 people and caused significant damage to crops and livestock. The flood and flash flood can cause fish to migrate or become trapped, leading to significant losses for local fishermen. The floodwaters can also bring in pollutants and sediment that can harm the delicate aquatic ecosystem, making it difficult for fish and other aquatic species to thrive. Floods and flash floods can result in loss of life, property damage, and displacement of people. Additionally, the floodwaters can damage or destroy fishing gear and equipment, causing financial losses for fishermen. The long-term impact of floods on the fisheries can lead to reduced catches and income, making it difficult for local fishermen to support themselves and their families. This, in turn, can have a ripple effect on the entire community, as the fishing industry provides important economic benefits to the region. Hossain et al. (2020) discovered that the increased frequency of floods has resulted in declining fish populations and reduced income for local fishermen and women. To mitigate the impact of flooding, the government of Bangladesh has implemented various measures, including the construction of embankments and the development of early warning systems. However, much more needs to be done to address the root causes of flooding and build resilience in vulnerable communities and also important to implement measures to reduce the risk and impacts of these events, such as early warning systems and infrastructure improvements.

Drought

Drought in Hakaluki Haor can have a significant impact on the local fish production. Around 17% of stakeholders perceived drought as a major concern, according to the stakeholder perspective (Fig. 2). The region's reliance on rain-fed agriculture and lack of irrigation infrastructure exacerbates the impact of drought

on crops and livelihoods. The prolonged droughts of 2019 and 2020 caused significant losses in agricultural production and livestock, resulting in food insecurity and poverty among vulnerable communities. This can lead to a decline in the number of fish in the Haor, reducing the catch for local fishermen. The drought can also cause changes in water temperature and quality, which can harm the health of fish and other aquatic species. Additionally, the reduced water levels can make it difficult for fishermen to access areas where fish are abundant, leading to reduced income and financial hardship for the local fishing community (Hossain et al. 2020, Islam et al. 2021, Rahman et al. 2021). The impacts of drought on the fishing industry can have long-lasting effects, making it difficult for the community to recover from the adverse effects of this weather phenomenon. Therefore, it is crucial to monitor and manage drought impacts on freshwater ecosystems and the communities that depend on them.

Siltation in beel

Siltation is a significant environmental concern in the Hakaluki Haor wetland ecosystem. The beels are highly productive ecosystems, providing a vital source of livelihood for the local communities. However, excessive sediment deposition, caused by natural factors, has led to a decline in the ecological health and productivity of these wetlands. Sedimentation is primarily caused by soil erosion, deforestation. Stakeholder perception indicates that siltation in beels is a concern for 37% of the participants (Fig. 2). The siltation process alters the hydrological regime of the beels, resulting in changes in water quality, temperature, and dissolved oxygen levels, which have a significant impact on the aquatic biota. The accumulation of sediment in the beels leads to a decrease in their water depth, thereby affecting their ecological health and productivity. CWBMP-DOE-CNRS (2005) and Khan (2011) have documented the severity of siltation in the Hakaluki Haor wetlands and highlighted the need for effective management strategies to control sedimentation rates and preserve the ecological integrity of these vital ecosystems.

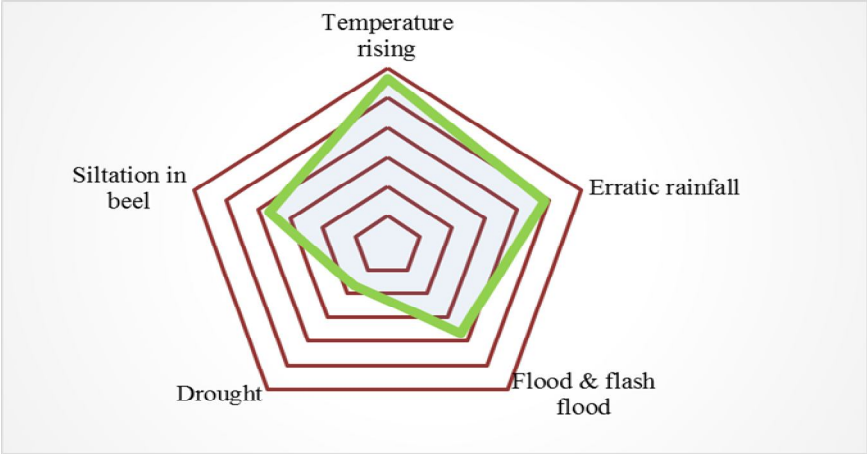

Fig. 2. Radar chart of climatic factors impacts on fish production.

Anthropogenic factors

Overfishing

Overfishing is a significant problem, with potential impacts on the sustainability of fish populations and their habitats. The stakeholder perception on overfishing in the study area revealed that it is considered a major threat to aquatic biodiversity and fish production. The majority of the stakeholders surveyed identified

overfishing as a significant issue, with 52% reporting it as a concern (Fig. 3). This indicates that overfishing is affecting the livelihoods of local communities who rely on fish as a primary source of protein and income. The stakeholders perceived overfishing to lead to a decline in fish population and reduced biodiversity, which can have negative long-term consequences for the ecosystem. For example, Pauly et al. (1998) found that overfishing had caused a 90% decline in the biomass of large predatory fish. Overfishing in Hakaluki Haor can have negative impacts on fish production by depleting fish populations, causing an imbalance in the ecosystem, and reducing the ability of the environment to sustainably support fish populations (Aziz et al. 2021). When too many fish are harvested from the Haor, the fish population that remains can face increased challenges, which can lead to lower growth rates, reduced reproductive success, and lower fish production. Additionally, overfishing can also lead to the decline of other species that are important to the ecosystem, further exacerbating the impact on fish populations (Bjorksten 1981). To maintain sustainable fish production in Hakaluki Haor, it is important to implement measures to reduce overfishing and ensure that fish populations are managed in a responsible and sustainable manner.

Discard non-target species

Discard bycatch, the non-target species the practice of throwing back unwanted or non-target species that are caught during fishing operations, can have significant impacts on low fish production. According to the stakeholder perception study, discard bycatch was identified as a significant concern by 23% of respondents (Fig. 3). These stakeholders perceived that the practice of discarding bycatch negatively impacts aquatic biodiversity, particularly in terms of the loss of non-target species and the disruption of the ecosystem's balance. Kelleher (2005) estimated that up to 40% of the fish catch is discarded, resulting in the loss of around 38 million tons of fish each year. This has a significant impact on fish populations, as discarded fish are often juveniles that have not yet reached maturity and would have contributed to future reproductive success. Furthermore, the practice of discarding can also affect the structure and function of ecosystems, as bycatch species play important roles in food webs and nutrient cycling. Thus, measures to reduce bycatch and promote sustainable fishing practices are crucial for maintaining the productivity and health of open water ecosystems. This can occur for several reasons: By catch that is discarded represents a waste of resources, including the time and effort spent catching the fish and the fuel and other costs associated with fishing operations. Many bycatch species are not adapted to survive after being caught and thrown back into the water and the mortality rate can be high, further reducing fish populations. It can have unintended impacts on other species, including the destruction of habitats and the spread of disease. Bycatch can also include target species, further reducing the overall abundance of fish in the Haor. Pitcher et al. (2009) emphasized the need for innovative solutions to reduce bycatch and promote sustainable fishing practices, including the development of new fishing gear and techniques, as well as improvements in fisheries management policies. Srinivasan et al. (2010) highlighted that these losses have a significant impact on the availability of fish for human consumption and the livelihoods of fishers, particularly in developing countries where fish is a major source of protein and income.

Uses of destructive fishing gear

Destructive fishing gear is a major threat to the health of ecosystems, as it can cause significant damage to habitats and result in the unintended catch and mortality of non-target species. Examples of destructive fishing gear include seine net and gillnets, indiscriminately catch and kill a large number of non-target species, including juveniles, which disrupts the delicate balance of the ecosystem and result in high levels of bycatch. A large number of responders, around 67%, indicated that using harmful fishing gear negatively impacts Hakaluki Haor fisheries (Fig. 3). These findings suggest that the use of destructive fishing gear is a significant threat to the sustainability of fish production and aquatic biodiversity. Sala et al. (2018) estimated

that destructive fishing practices affect the ecosystem. Furthermore, a study by Kelleher and Kenchington (1992) noted that the use of destructive fishing gear has contributed to the decline of many fish populations and threatened the sustainability of fisheries. Additionally, these methods can destroy habitats that support fish populations. Furthermore, the use of such fishing gear also leads to overfishing of targeted species, resulting in a decline in their populations and reducing the overall productivity of the fishery. All these factors contribute to a decline in the overall health and resilience of the Hakaluki Haor fishery, affecting not only the fish populations but also the livelihoods of the local fishing communities that rely on these resources. To mitigate this threat, effective management strategies are needed that promote sustainable fishing practices and discourage the use of destructive fishing gear. Such strategies should be developed in consultation with local communities and other stakeholders to ensure their effectiveness and sustainability.

Beel drying

Beel drying in Hakaluki Haor has had a devastating impact on the local fisheries. The draining of the beel, which is often done for harvesting all the fishes, reduces the water level and leads to the death of fish and other aquatic organisms completely. Around 47% of the respondents indicated that the drying of beels adversely affected the Hakaluki Haor wetlands (Fig. 3). This decrease in the fish population not only affects the livelihoods of local fishermen who rely on the Haor for their livelihoods, but also contributes to the decline of fish species and biodiversity in the ecosystem. This method used to harvest all the fishes from Haor. While this practice can increase the profit margin of the fishers, it can also have negative impacts on fish populations and biodiversity in the wetlands. A study by Naser and Thompson (2011) found that beel drying can result in the loss of fish habitats and reduced fish productivity, especially reduce the brood fishes.

Use of urea fertilizer

The application of urea fertilizer to harvest the beel (natural depression) fish is a destructive technique for the ecosystem. Approximately 37 percent of the respondents agreed that using urea fertilizer had a negative effect on aquatic biodiversity (Fig. 3). Applying urea fertilizer can have negative impacts on the production of beel (Aziz et al. 2021). Urea fertilizer can increase the levels of nitrogen and phosphorus in the water. This can result in eutrophication, which can reduce the amount of dissolved oxygen in the water. This can negatively impact the health of the eel fish population, leading to decreased production. To minimize these negative impacts, it is important to carefully monitor and manage the amount of fertilizer applied in the area.

Agriculture intensification

Hakaluki Haor, a large wetland ecosystem in Bangladesh, has been traditionally used for fish production through capture fisheries. However, agricultural intensification in the region, which involves the increased use of chemicals and other inputs in agriculture, can lead to water pollution and the degradation of water quality in the Haor. This pollution not only harms the health of fish and other aquatic life, but also affects the livelihoods of local fishermen who rely on the Haor for their fishing. Stakeholder perspectives indicated that 45% of respondents believed that agriculture intensification caused a decline in fish production in the Hakaluki Haor wetland habitat (Fig. 3). Additionally, agriculture intensification can lead to soil erosion and the loss of important habitats for fish and other aquatic species, further degrading the ecosystem and contributing to the decline of biodiversity. Ahmed et al. (2018) found that the use of agrochemicals and unsustainable agricultural practices have led to a decline in fish diversity and abundance in Hakaluki Haor. These negative impacts on the fishing industry and the ecosystem underscore the importance of sustainable agriculture practices that prioritize conservation and protect the health of the Haor and its inhabitants.

Water pollution

Water pollution is a major threat to fish production in Hakaluki Haor, Bangladesh. The wetland ecosystem has been severely impacted by the discharge of untreated industrial and municipal waste, as well as the extensive use of agrochemicals in nearby agricultural fields. These pollutants have contaminated the water and sediment, altered the physicochemical properties of the ecosystem and adversely affected fish habitats and biodiversity. 23% of stakeholders perceive water pollution as a significant threat to the health of the beel ecosystem (Fig. 3). High levels of heavy metals, pesticides, and organic pollutants in the water and sediments of Hakaluki Haor, which can accumulate in fish tissues and pose a risk to human health (Ali et al. 2019, Mia et al. 2019). The high levels of water pollution have also led to a decline in fish production and a loss of income for the local fishing communities. To address this issue, measures such as the treatment of industrial and municipal waste, the promotion of organic farming practices, and the regulation of pesticide use need to be implemented to improve water quality and protect fish habitats in Hakaluki Haor.

Destruction of habitats

The destruction of habitats in Hakaluki Haor is a major factor contributing to the declining fish production in the wetland ecosystem. The wetland ecosystem in the Haor is critical to the survival of many fish species, including their breeding, spawning, and feeding activities. However, human activities such as deforestation of swamp forest, land-use changes, and unsustainable fishing practices have led to the degradation of habitats, resulting in the loss of fish diversity in the Haor. The degradation of habitat was considered by 48% of respondents as a serious danger to fishing resources in the stakeholder perception survey (Fig. 3). Islam et al. (2018) found that the destruction of habitats has led to a decline in the abundance and diversity of fish species in Hakaluki Haor. To address this issue, measures such as the restoration of degraded habitats, the implementation of sustainable fishing practices, and the conservation of wetland ecosystems need to be put in place to ensure the long-term sustainability of fish production in the Haor.

Changes in water flow

Changes in water flow patterns in Hakaluki Haor have had a significant impact on fish production in the wetland ecosystem. The construction of embankments, dams, and irrigation canals in the surrounding areas has altered the natural water flow patterns and disrupted the seasonal flooding that is necessary for fish breeding and spawning. The changes in water flow have also led to the drying up of wetland areas, reducing the availability of fish habitats and causing a decline in fish populations. Changes in water flow were considered a serious issue by 13% of the participants, in accordance with stakeholder viewpoint (Fig. 3). This could indicate concerns about the effects of human activities, such as damming or diversion of water, on the natural water flow patterns in the region. The flow of water from the Haor to the main river has decreased by 44% over the past 30 years, which has had a significant impact on the fish production and livelihoods of local fishing communities (Ali et al. 2017). To mitigate the negative impacts of changes in water flow, measures such as the restoration of natural water flow patterns and the promotion of sustainable water management practices need to be implemented to ensure the long-term sustainability of fish production in Hakaluki Haor.

Change the migration route of brood fishes

Changing the migration route of brood fishes in Hakaluki Haor has been identified as a key factor contributing to the decline in fish production in the wetland ecosystem. Around 30% of the stakeholders agreed that the change in the brood fishes' migration route was a serious problem that had an immediate effect on fish productivity (Fig. 3). The construction of embankments and other infrastructure in the surrounding areas has disrupted the natural migration patterns of brood fishes, making it difficult for them to reach their breeding and spawning grounds. This has resulted in a decline in fish populations and a loss of income for the local

fishing communities. The perception of the stakeholders revealed that change the migration route of brood fishes were considered a serious problem influencing fish production by 30% of the stakeholders (Fig. 3). To address this issue, measures such as the creation of fish passages and the restoration of natural migration routes need to be implemented to ensure the long-term sustainability of fish production in Hakaluki Haor. Islam et al. (2017) reported that the construction of a fish passage in the Haor improved the migration of brood fishes and led to an increase in fish populations and biodiversity in the wetland ecosystem.

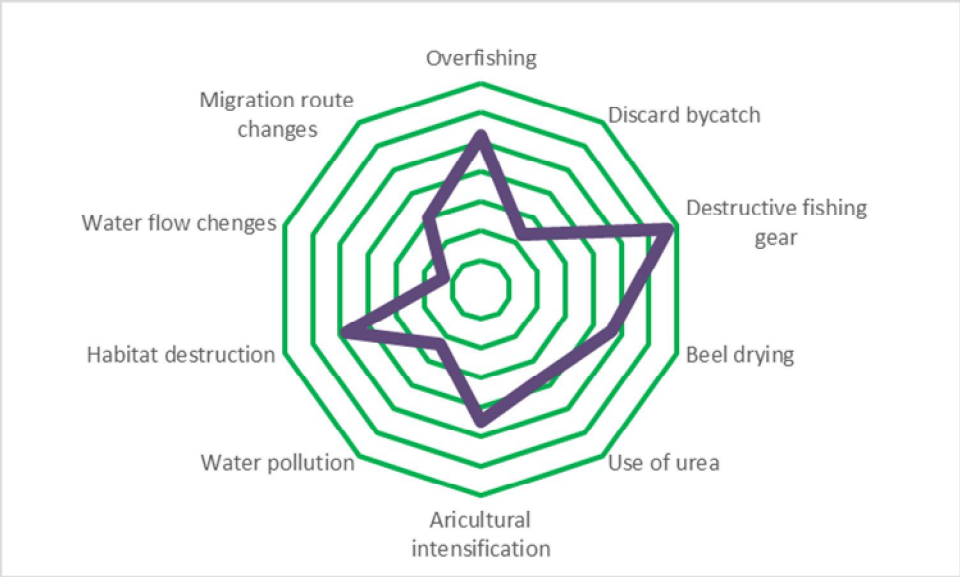

Fig. 3. Radar chart of manmade factors impact on fish production.

Conclusion

The stakeholder perceptions on the impacts of climate on the Hakaluki Haor indicate that overfishing, the use of destructive fishing gear, and beel drying are perceived as the major threats to fish production. These activities are also perceived to be associated with fish biodiversity, particularly in terms of habitat destruction, water pollution, and migration route changes. Climatic factors, such as rising temperatures and erratic rainfall are perceived as the major threats, leading to changes in the distribution and abundance of aquatic species. Drought and siltation in beel were perceived as less severe but still significant threats to aquatic production. These findings highlight the need for effective climate change adaptation and mitigation strategies that take into account the perceptions of all stakeholders involved, to ensure the sustainability of aquatic production and the livelihoods of local communities. The impact of climate change on the Hakaluki Haor fisheries in Bangladesh is significant and requires urgent action to mitigate its adverse effects. Policies and measures to promote sustainable fishing practices that consider the ecological and social factors of the region are necessary. Moreover, efforts to address the socio-economic impacts of climate change on fishing communities in the region are crucial to ensure their resilience and adaptation to changing climatic conditions.

Recommendations

To sustainably manage the fisheries in Hakaluki Haor, the following recommendations can be considered:

- The adverse climatic events, such as rising temperatures, erratic rainfall, and siltation in beel, have had a negative impact on fish breeding. Consequently, it is crucial to implement measures aimed at protecting and restoring various habitats, including wetlands, grasslands, and swamp forests.
- Encouraging the use of recommended fishing gear, avoiding fishing during the breeding season, and promoting the use of selective fishing methods can help protect fish populations.
- Regular monitoring and evaluation of the Haor's ecosystem, fish populations, and fishing activities can help identify any issues and inform the development of management plans.
- To minimize the impact of bycatch on fish production in Hakaluki Haor, it is important to implement measures to reduce bycatch, such as using gear that is less likely to catch non-target species, and to develop alternative methods for handling bycatch that minimize mortality and negative impacts on the ecosystem.
- Providing training and education programs to help fishers improve their skills and increase their knowledge of the latest fishing techniques, safety measures, and sustainable practices.
- Encouraging and supporting alternative livelihoods, such as cage aquaculture (Gupta et al. 2012), carp polyculture in the peripheral water bodes of Haor (Haque et al. 2003), etc. to diversify the income of fishers, and reduce the fishing pressure on natural water bodies.
- Promoting value-addition activities, such as processing and packaging of fish products, to increase the value of the fish catch and improve the income of fishers.
- Improving market access for fish products, such as by establishing cold storage facilities, to help fishers sell their catch at better prices.
- Implementing watershed management practices, such as reforestation and soil conservation, to improve the water quality and fish habitat in the Haor.

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[i] Beel is a small, lake-like water body characterized by its static water conditions, which may occasionally dry up during the winter season. Although smaller in size compared to a Haor, it still maintains the fundamental features of a typical beel.

[ii] The term Haor, also known as a back swamp, denotes the bowl-shaped large tectonic depression that receives surface runoff water from rivers and canals.