Original Research Article

Securing livelihoods through pond fisheries management in climate change scenario: Evidence from *haor* region of Bangladesh

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ABSTRACT

Aims: To identify the potential environmental impacts and influence of climate change on the pond fishery in *haor* region and impact of exotic species on the indigenous species through aquaculture.

Study Design: An investigation on the influence of the pond fishery approach to determine whether the approach is successful with respect to the climate change impacts in the *haor* area.

Place and Duration of Study: The study sites are located in five *haor* districts in Bangladesh for a period of one-year (May 2018 – April 2019) covering HILIP working area.

Methodology: The study includes collection and analyses of both quantitative and qualitative data. For quantitative study, 92 sample households in 58 unions of 28 upazilas (sub-districts) in five project districts were randomly selected. Fish catch data, including information on species composition, production and sale were collected from perennial and seasonal ponds. The qualitative primary data obtained through in-depth interviews, key informants interviews and focus group discussions have been used in this paper.

Results: Fish production was found to be better at perennial ponds, but not significantly more than that in the seasonal ponds. However, biodiversity was found to be better in seasonal ponds and greater than that in the perennial ponds. The findings clearly support the observation that pond fish culture is an attractive activity for *haor* people, especially those who are able to run both perennial and seasonal ponds and manage minimum feeding requirements, maintain those and market the outputs effectively. The present study fills gaps in existing knowledge of fish pond culture diffusion in *haor* region of Bangladesh.

Conclusions: Pond fishery appears to perform better so, aquaculture production would mitigate some lost capture fisheries in the *haor* area of Bangladesh. Existing cultural practices could support experimentation and learning under future initiatives in the *haor* area. Pond fishery in the *haor* area mainly has an income-generating feature and less probability of being affected by climate change impacts. However, future initiatives should emphasize on culturing fish, which has the potential of balancing the *haor* ecosystem.

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Keywords: *Haor*, Climate change, Perennial pond, Seasonal pond, Species composition

1. INTRODUCTION

The hydrology and topography of the Meghna Basin have led to the development of *haor* ecosystem in the upper Meghna Basin. *Haor*s are low-lying, marshy depressions that turn into a vast expanse of water during the monsoon [1]. Water of the *haor*s recedes as the monsoon rains taper down, providing fresh nutrient rich lands for seasonal cultivation including aquaculture. Bangladesh is a country of vast *haor* resources covering an area of about 1.99 million hectares (19,998 sq. km) with a human population of

about 19.37 million [2]. Bangladesh is characterized by a tropical monsoon climate with significant variations in rainfall and temperature throughout the country. There are four main seasons in Bangladesh: i) the pre-monsoon during March through May, which has the highest temperatures and experiences the maximum intensity of cyclonic storms; ii) the monsoon from June through September, when the bulk of rainfall occurs; iii) the post-monsoon during October through November which, like the pre-monsoon season, is marked by tropical cyclones on the coast and iv) the cool and sunny dry season from December through February [1].

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In 2016, global fish and shellfish production reached a record 171 million tons and employed around 200 million people either directly or indirectly [3]. The quantity of finfish and shellfish used for direct consumption from aquaculture has surpassed that from wild fisheries and this gap is expected to widen as aquaculture continues to expand [3].

In 2016-17, Bangladesh fish and shellfish production reached a record 4.13 million tons and more than 11% of the total population of Bangladesh is employed either directly or indirectly in the fishery [4]. This sector is contributing significantly to food security through providing safe and quality animal protein; almost 60% animal protein comes from fish. The *haor* fisheries of Bangladesh support the livelihoods of millions of poor people, but landings and species diversity are believed to be declining because of high rates of exploitation and habitat degradation [5].

Bangladesh is extremely vulnerable to climate change impacts because of its geographical location, high population density, high levels of poverty and reliance of many households on, particularly, fisheries and agriculture. These impacts fall more heavily on the poor fisher and farmer communities. This is due to high influence of monsoon, too much water in the monsoon and too little water in the dry season. These have significant impacts on fish stocks in the rivers and wetlands. Besides, water management puts more difficulties towards the coping with climate change, especially, where riverbank erosion is threatening the embankments in addition.

Bangladesh has always been vulnerable to climate changes and the climate of the country is strongly influenced by the monsoon. Accurate information about the climate change situation at the national or sub national level is limited in the *haor* areas. Bangladesh is expected to experience an increase in mean annual temperature over the next century. The Implications of these climate change scenarios are that about 18% of current lowly flooded areas will be susceptible to higher levels of flooding, while 12-16% new areas will be at risk to inundation. This will increase the risk of estuarine salinity as well as inland water fisheries. Bangladesh' freshwater resources are at most risk from droughts and drainage congestion as well as lower dry season trans-boundary flows. Located on the floodplains of three major rivers, fed by an annual monsoon, Bangladesh is also under risk of more severe floods and cyclones. Backwater effect is pronounced in Bangladesh, particularly in the Meghna River Estuary, through which about 90% of the river water in the country discharges into the Bay of Bengal. It is important during the flood seasons. Acute situations are likely to occur all along the coastal area of Bangladesh, thus making the situation even worse. Simultaneously, increasing river morphological activities have resulted in erosion and loss of land at some locations and sedimentation at other places. Sedimentation and drainage congestion is hampering the withdrawal/flow out of the water from flooded areas, thus increasing the period of inundation.

Climate change (CC), particularly global warming, is having a demonstrable effect on the distribution and regional productivity of both terrestrial and aquatic organisms [6]. The projected effects of climate change on aquatic habitats and species, although fraught with uncertainty [7] are particularly relevant to society because of the importance of finfish and shellfish to food security, cultural heritage and/or the economics of dependent human communities [8], [9], [10], [11], [12].

In fact, Bangladesh has a couple of projects aiming at addressing climate change. However, none of those projects have any objective on fish stocks and the vulnerability of poor fisher's livelihoods,

especially, those who heavily depend on fisheries and aquatic resources. Bangladesh *haor* pond aquaculture has ample scope of development to strengthen the national economy. Haor Infrastructure and Livelihood Improvement Project (HILIP)-LGED has been involved in *haor* pond aquaculture not for the sake of aquaculture production increases alone; rather its goal has been to improve the socio-economic position and physical well-being of poor farmers involved in pond fishery. HILIP has been working within *haor* area by building the capacity of poor farmers with a view to improving the quality and quantity of their pond production.

In the recent years, small-scale floodplain aquaculture has become popular and is contributing, significantly, to country's total fish production. However, mass mortality of fishes in nature is not especially rare, but most often the phenomenon develops so unexpectedly that no biologist is on hand to trace its course or to identify the cause, except by inference [13].

The major challenges of this fast growing sector include –

- Depletion brood stock of potential species
- Scarcity of good quality fry and larvae
- Expansion of good aquaculture practices for ensuring food safety
- Climate change impacts on fisheries and aquaculture
- Gradual resource depletion of fishes in inland open water sector
- Increasing water logging, blocking migratory routes of many fish species

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2. MATERIALS AND METHODS

2.1 Study Area

The study area comprises five *haor* districts namely Netrokona, Sunamganj, Habiganj, Kishoreganj and Brahmanbaria in the North-Eastern Bangladesh, wherein lies 165 unions under 28 upazilas (sub-districts). The waters of these five districts are hydrologically connected and function as a unique ecosystem (Figure 1). The study has purposefully selected all five districts covering 28 upazilas (Table 1). Thereafter, a total of 92 *haor* ponds have been selected in 58 unions randomly. Two unions were randomly selected from each upazila and the ponds were distributed within the selected unions. The study employed data collection from June 2018 to April 2019. Status of *haor* ponds was examined in three ways. Firstly, the production from pond fishery was estimated by using data from household survey; secondly, by conducting Focus Group Discussions (FGDs) at upazila level with the help of a checklist and finally, by Key Informant Interviews (KIIs) at district level with the help of a KII checklist.

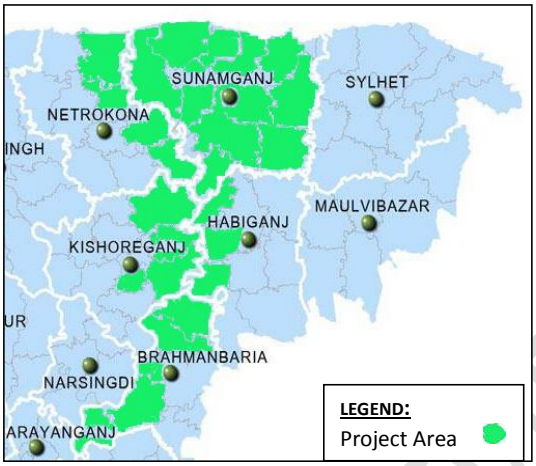

Fig. 1: Study Area Shown on Bangladesh Map

Table 1: List of Upazilas covered under HILIP.

Division	District	Name of Upazilas
Mymensingh	Netrokona	Khaliajuri, Kolmakanda, Madon, Mohanganj
Sylhet	Sunamganj	Sunamganj Sadar, DakshinSunamganj, Dherai, Bishwambarpur, Tahirpur, Jamalganj, Sulla, Dowarabazar, Dharmapasha, Chhatak, Jagannathpur
	Habiganj	Azmiriganj, Lakhai, Baniachong
Dhaka	Kishoreganj	Itna, Mithamoin, Astagram, Nikli
Chittagong	Brahmanbaria	Nasirnagar, Nabinagar, Sarail, Ashuganj, Brahmanbaria Sadar, Bancharampur

2.2 Data Collection

Source of data: Both primary and secondary data are used for the study. Primary data were collected through the survey using random sampling method (questionnaire, IDI - In Depth Interview) from four (4) upazilas in Netrokona, nine (9) upazilas in Sunamganj, four (4) upazilas in Kishoreganj, three (3) upazilas in Habiganj and six (6) upazilas in Brahmanbaria. In addition, Focus Group Discussions (FGDs) were held in 28 upazilas and Key Informant Interviews (KIIs) held with policy planning and implementation personnel in five districts (DoF, HILIP and WorldFish). Besides, reviews of published articles, government websites and policy documents were conducted to gather information on the local issues and initiatives in the *haor* areas. Collected data have been stored using MS-Access and MS-Excel. Data and information have been analyzed using SPSS and other software.

Data collection method: Primary data from household respondents were collected using questionnaire interview and in Depth Interviews (IDIs), Focus Group Discussions (FGDs) and cross-check interviews with Key Informants. The interview schedule was developed in a logical sequence, so that local people and pond owners could answer, systematically. The questionnaire, interviews were conducted during the study period at the households in five districts to the randomly selected 13 pond owners in 7 unions of

Netrokona, 34 pond owners in 25 unions of Sunamganj, 14 pond owners in 7 unions of Kishoreganj, 9 pond owners in 7 unions of Habiganj and 22 pond owners in 11 unions of Brahmanbaria. A total of 28 FGD sessions was conducted, where each group size of FGD was 10 to 16 participants. After collecting data through questionnaire, interviews (IDIs) and FDGs, cross-check interview were conducted with key informants at their offices.

2.3 Data Analysis

Mainly descriptive statistics were employed in analyzing the data. The collected data were verified to eliminate errors and inconsistencies. Any kind of inconsistency in the collected data was searched and avoided from the relevant data. The data were entered into the computer using MS Excel (Microsoft Excel) and analyzed using SPSS (Statistical Package for Social Science) by tabular and graphical method to attain the objectives of the study.

3. RESULTS AND DISCUSSION

3.1 Demographic Characteristic of Pond Owners

The average sizes of the sampled households were 5.73, 5.57, 5.62, 6.89 and 5.38 in Brahmanbaria, Kishoreganj, Netrokona, Habiganj and Sunamganj districts respectively. The overall size of sampled households was 5.67, which was higher than the national average of 4.06 [14]. Population per household was found highest in Habiganj (6.89). However, national statistics reveal that household size is highest in Sunamganj, Habiganj and Brahmanbaria districts (5.29-5.86) and higher in Netrokona and Kishoreganj districts (4.85-5.28) [15]. Table 2 shows the demographic characteristic of sampled households, i.e. pond owners' household and distribution of males and females. The distribution shows that in these fish farming households there are 118 males for every 100 females.

Table 2: District wise distribution of household members according sex and family size

Demographic characteristics	B. Baria	Kishoregonj	Netrokona	Habiganj	Sunamganj	All districts
Total sampled household	22	14	13	9	34	N=92
Male	69	40	42	36	96	283
Female	57	38	31	26	87	239
Total population	126	78	73	62	183	522
Population per household	5.73	5.57	5.62	6.89	5.38	5.67

3.2 Main Occupation of Pond Owners

Respondents at households were asked to describe their main occupations and income from different sources prior to the IDIs. The main occupation was found to be fish culture and 64% of households were occupied with it. However, agriculture, business, fish trading, service, skilled labour sale, pottery, and fishing comprised occupation of about 34% households. Besides 2% households reveals dependents and students. **Figure 2** shows details status of main occupation of pond owner's.

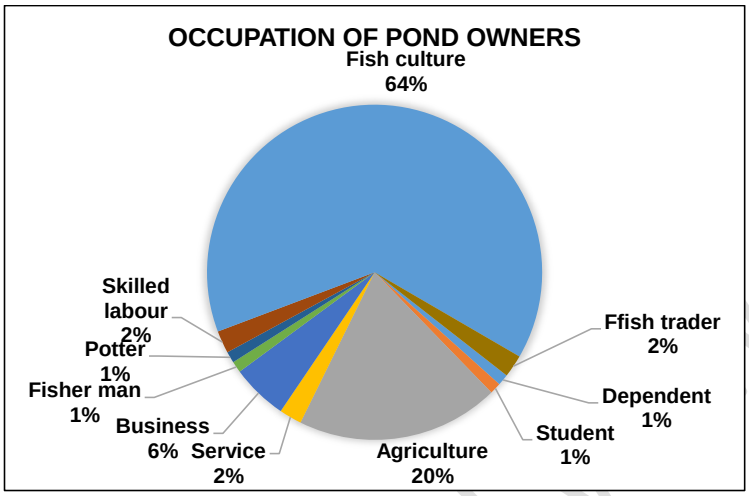

Figure 2: Main occupation of Pond owner's in HILIP sites

3.3 Status of Perennial and Seasonal Ponds

In *haor* areas, fish are cultivated in both perennial and seasonal ponds to meet the demand of present food supply of the area as well as of the country. The optimum production of fish per hectare in fishponds is vital for benefitting the farmers. Fish production in *haor* ponds (perennials and seasonal) remains vital in providing food, income and employment opportunities for millions of poor people. Recently, Bangladesh's aquaculture sector has developed rapidly; consequently, the production and system diversity continue to grow. Many people regard aquaculture as the most realistic way to secure the fish supply needs. Besides, production techniques are well established: inputs such as seed and feed are widely available.

Present study determines the average area (decimal) of both perennial and seasonal ponds and it reveals that the average area of perennial ponds in Brahmanbaria, Kishoreganj, Habiganj, Sunamganj and Netrokona districts are 79, 71, 42, 34.5 and 71 decimals respectively. Simultaneously, the average of area of seasonal ponds are found to be 43.6, 80, 92, 54.1 and 42.4 decimals in Brahmanbaria, Kishoreganj, Habiganj, Sunamganj and Netrokona districts respectively. Maximum perennial pond area (decimal) was found in Brahmanbaria district and minimum pond area in Sunamganj district. Besides, maximum seasonal pond area was found in Habiganj district and minimum pond area in Netrokona district.

Typical fish production yields from perennial pond aquaculture are between 23.2 and 30.3 Kg/decimal compared to fish yields of 12.6 – 26.8 kg/decimal from seasonal pond aquaculture. *Haor* ponds yields are comprised of both exotic and indigenous fish species. Besides, a small percentage, (usually 8% in Perennial ponds and 15% in seasonal ponds) of the total catch weight is made up of indigenous *haor* fish species. Pond fish culture in seasonal ponds shows a maximal production in Kishoreganj district and minimal production in Brahmanbaria district. Fish culture in perennial ponds shows maximum production also in Kishoreganj district and minimal production in Netrokona district. Figure 3 shows the average production (Kg/decimal) of both perennial and seasonal ponds in the study areas.

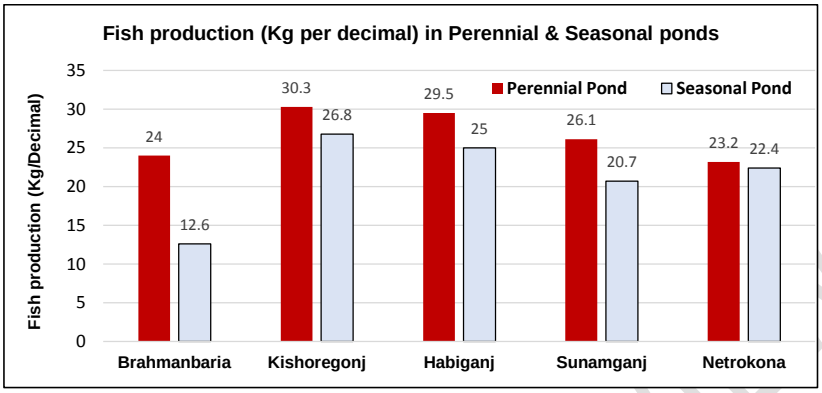

Figure 3: Average fish production (Kg/decimal) in Perennial and Seasonal ponds

3.3 Assessment of Impact of Pond Fish Culture

Local economies can gain significantly from both direct benefits of *haor* pond aquaculture activities, (i.e. increased production, profits, incomes, etc.) and indirect benefits of employment and service provision linkages created by the aquaculture activities. The average fish price (per Kg) from perennial pond aquaculture are between Tk. 97 and Tk. 123 per Kg compared to fish price (per Kg) of Tk. 106 – 172 per Kg from seasonal pond aquaculture. Using available information on cost and benefit the study reveals that pond fish farming provided an acceptable benefit in both perennial and seasonal ponds. The average benefit per decimal per year from perennial ponds varies between Tk. 1134 and Tk. 2113, and that from seasonal ponds varies between Tk. 1143 and Tk. 1664. Pond fish culture in perennial ponds shows least benefit in Netrokona district and highest benefit in Habiganj district. In contrast, pond fish culture in seasonal ponds shows least benefit in Sunamganj district and most benefit in Habiganj district. Figure 4 shows a variety of benefits per decimal at different districts for both perennial and seasonal ponds.

Using cost benefit information for both perennial and seasonal ponds the study reveals that the maximum benefits from perennial and seasonal ponds were found to be Tk. 103,956 (US$ 1268) and Tk. 130,247 (US$ 1588) and, minimum benefits were found to be Tk. 40,377 (US$500) and Tk. 61,843 (US$ 754) respectively.

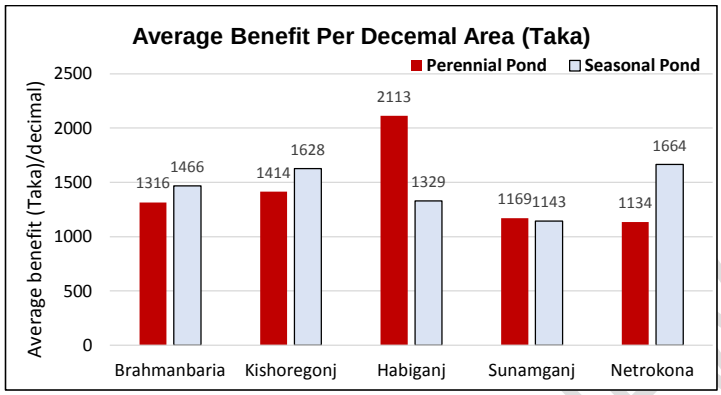

Figure 4: Average benefit (Taka) from fish culture at per decimal area

3.4 Assessment of Fish Culture: Impact of Exotic Species on Natural Fish Production

Haor pond aquaculture yields are mostly comprised of both indigenous and exotic fish species. The study area comprises exotic species, e.g., Tilapia, mono-sex Tilapia, Silver carp, Thai pangus, Common carp, Thai sarputi, Grass carp and most of these are available in culture fishery. Production in floodplains and *beels* has increased due to stocking with carp fingerlings, *Beel* nursery program and the strengthening of conservation measures. Besides, the production of *haor* pond fishery has gradually been increasing due to training provided through several projects, mostly HILIP and Climate Adaptation and Livelihoods Protection Project (CALIP) and stocking with carp fingerlings. Many inland aquaculture species used in Asia are exotic. Exotic fishes are those species of fish, which are not native and introduced from other countries to the local areas. Exotic animals are defined as "species occurring outside of its natural range". Among the numerous reasons for the introduction of exotic aquatic animals into countries, aquaculture development is said to be a main motive [16].

Fish production yields from perennial ponds are comprised of 24% indigenous cultured fish, 68% exotic fish and 8% indigenous non-cultured fish. Fish production yields from seasonal ponds are comprised of 18% indigenous cultured fish, 67% exotic fish and 15% indigenous non-cultured fish**.** Overall fish production yields from both perennial and seasonal ponds are comprised of 22% native cultured fish, 67% exotic cultured fish and 11% indigenous non-cultured fish (Figure5).The predominance of 6-7exotic fish species are found in the *haor* ponds. Some of these species may pose a threat to indigenous biodiversity, through their escape and establishment of feral populations in adjacent *haor* water bodies.

Mola carplet (*Amblypharyngodon mola*) is a nutrient-rich small fish that provides essential nutrients, in particular, vitamin A, calcium, iron and zinc and used as food fish in Bangladesh. HILIP also introduced Mola carplet fish along with other natural indigenous species in *haor* ponds. Consequently, a good harvest of mola fish reveals successful HILIP intervention in both perennial and seasonal ponds. Overall, the mola comprised of about 1% and 2.88% in perennial and seasonal ponds respectively. However, in Sunamganj and Habiganj districts mola fish contributed 5.95% and 3.75% of production in seasonal and perennial ponds respectively. The mola culture has no adverse environmental impact and does not hamper existing fish. The mola fish culture has become popular among farmers in *haor* region in Bangladesh. This fish is available in the rivers, streams, beels and lakes and inundated fields throughout Bangladesh. However, there has been a decline in the areas of inland water and inundation that

significantly reduced the vital habitat for its recruitment and stocking. The taxonomic group used in the catch analysis of the pond fishery and taxa contributed to each group (Native cultured fish, Exotic cultured fish and natural non-cultured fish) by % to the catches is given in Annexure 1.

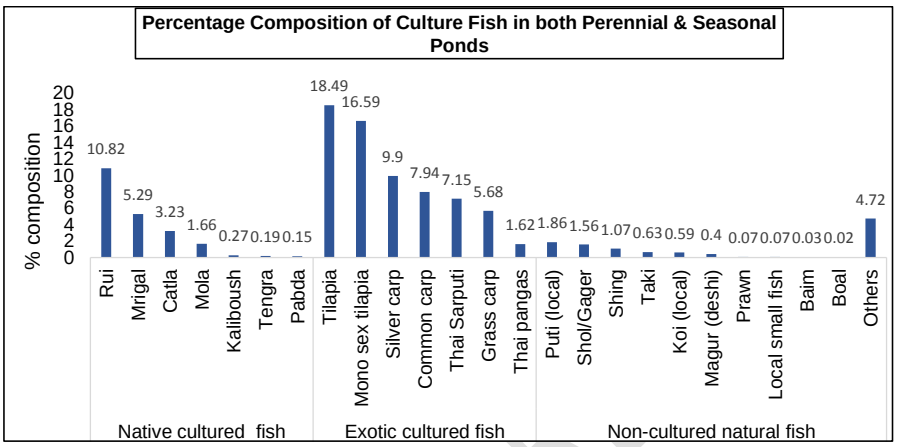

Figure 5: Overall Fish Production Yields from both Perennial and Seasonal Ponds

3.5 Empowerment of Women through Pond Fish Culture

Traditionally, Bangladeshi women have been involved in fish culture or fishing related activities, especially, it has been at the post-harvest stage of the production process. At the pond aquaculture level the skills and knowledge from training are still very much in evidence for men and much of the methodologies and protocols are being practiced [17]. However, *haor* pond aquaculture does create the situations for a diversification of their involvement, through the service provision opportunities, such as cleaning weeds, carrying soil up pond bank, pond cleaning, testing water quality (colour), applying fish feed, fertilizer and lime and participating in the decision making process. In a perennial pond, women were observed having a more significant role in the process, either as pond culture operators or as household heads. In Depth Interviewed revealed that the *haor* pond culture has greatly enhanced their involvement in the pond culture leading to new economic opportunities.

Among various roles, feeding is vital for women and it has been revealed that 48% and 15% women are directly involved with feeding fish and mixing up feeds respectively. Besides, they are also involved with guarding, cleaning water hyacinth, examining water quality (colour) and looking after other related activities. During the dry season, post-harvest processing and management needs significant contribution of women in the *haor* area. Grading and drying are the most laborious but important economic post-harvest activities and it has been revealed that 76% and 11% women are directly involved with grading and fish drying respectively. Besides, they are also directly involved with cleaning the fish, maintaining accounts and helping during catching fish. The roles of women in overall pond fish culture and post-harvest management over the study area is shown in Figure 6.

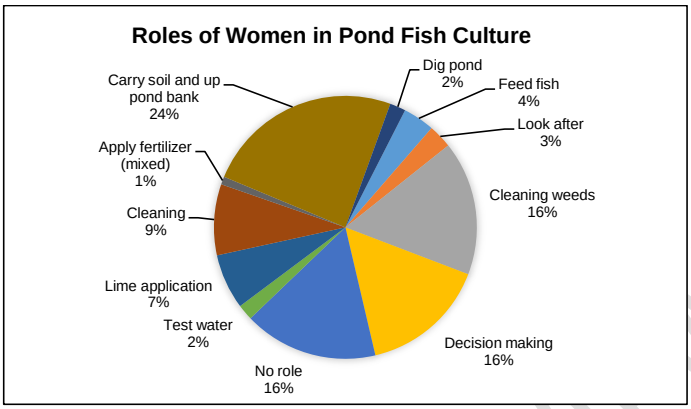

Figure 6: Overall Roles of Women in Pond Fish Culture

3.6 Environmental Impact

Impact of Flash Flood: *Haor* is a basin like structure where water remains either stagnant or in flash flooding condition during early monsoon. Flash flood damages Boro crop and pond aquaculture, so that the present study was conducted to know the impact of flash flood. Primary data were collected through IDIs from 92 pond owner households covering 28 upazilas. Most of the respondents were pond owners as well as farmers. Among the different categories of flood, flash flood damages the pond fishery most. Among the respondents, 23%, 28% and 20% revealed that it damaged, washed out fishes and destroyed banks of the pond respectively. Only 3% respondents revealed that ponds were submerged by flash flood. However, 26% respondents stated that no impact occurred on pond aquaculture due to flash flood. As flash flood often causes considerable, localized damage to pond fishery, particularly in the north, northeast part of the *haor* districts so, 26% respondents does not face any impact on their perennial pond aquaculture. Flash flood is the common phenomena in the *haor* area and usually it damages pond fishery and create negative impacts on the local economy. Figure 7 shows the impact of flash flood on pond fish in the HILIP areas.

The *haor* area in Bangladesh is susceptible to flash flooding from water coming down hilly streams emerging out of Khasia- Jaintia Hills located in the Indian Territory. There are many *haor*s in Bangladesh, where remains either stagnant or in flash flooding condition during the months of June to November [18]. Flash floods occurring at intervals damage crops and flashes out fish in ponds into the *haor* area. Exotic species of fish cultured in ponds escape, quite often during a flash flood, to wide *haor* area, exposing the local species to be affected by these species.

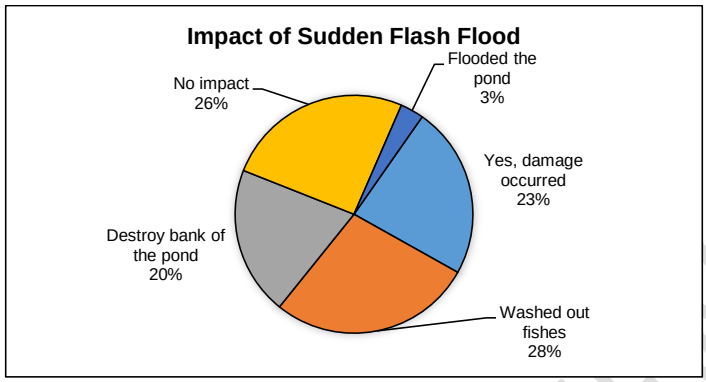

Figure 7: Communities' Perception on Sudden Flash Flood

3.6.1 Impact when Number of Fish Culture Ponds Increase

Haor area is very important for the production of fishes, especially open water fishes. However, recently pond aquaculture production, both perennial and seasonal has increased. Overall, 29% of the respondents, who make the major portion of pond fish culturist, said that no detrimental effect will occur, if pond fish culture is extended in the *haor* area. However, 22% respondents' reveals that this increased may affect local natural species of fishes and 21% respondents view that agricultural land will decrease if pond aquaculture increased in *haor* area. Besides 6% respondents, views that this might destroy the environmental balance and may cause of decrease water lily, which is very common in *haor* area in Bangladesh.

3.6.2 Impact when Cultured Fish Escape to *Haor* Water

According to the study, 67% of the respondents said that financial loss would occur when cultured fish escapes into *haor* water due to any environmental impact. However, 27% respondents reveal that no impact will occur. Besides, 8% respondents expressed that people will lose interest to fish culture. Figure 8 shows respondents' views regarding impacts if cultured fish escape to *haor* waters.

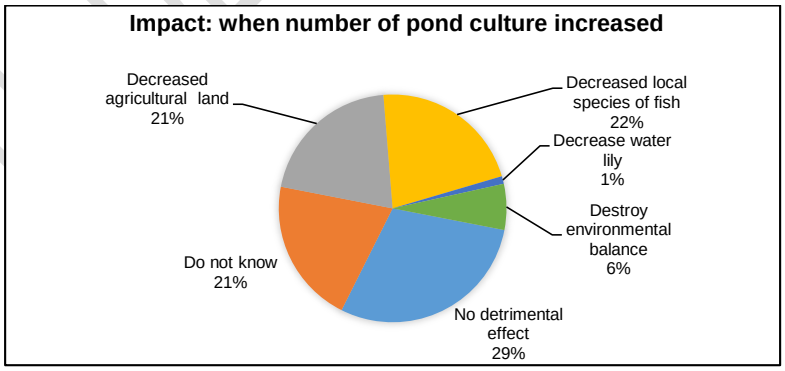

Figure 8: Communities' perception regarding impact of fish culture when number of pond increased

3.6.3 Impact on Pond Fish Culture – when Insecticide Applied in Agriculture

Aquaculture in general is highly sensitive to adverse environmental changes. According to the study, 45% respondents reveal that there will be no impact on pond aquaculture, if insecticides are applied to agricultural field. However, 22% respondents revealed that agricultural insecticide will reduce fish growth and about 22% respondents' viewed that fish disease will occur because of agricultural insecticide. Opinions on different types of impact that may occur due to application of insecticide in agricultural field revealed that 5%, 2% and 3% respondents thought that as a consequence, dead fish will float on water, water be polluted and infection in fish body will occur respectively. Only 1% respondents stated that eggs of local fish will be destroyed due to insecticide use in agriculture field.

3.6.4 Summary of Environmental Impact related KII Results

Summary of opinions of Key Informants on environmental impact includes the following:

i. Intensification of fish culture in both perennial and seasonal ponds is a lower area in *haor* districts will not create any adverse or conflicting impact on ecology;

ii. Pond culture interventions did not produce as of now any negative effects on the environment;

iii. Water level rise in lean season (winter) due to sea level rise is not clearly perceptible as yet in the *haor* region, so question of adverse effects does not arise;

iv. Climate change, especially temperature has adverse effect on spawning of fish species. Due to siltation in the *haor* area water depth is reducing chronologically and water temperature is perceived to be rising nowadays, especially in the lower haor area; high temperature has adverse effect on spawning of fish. On the other hand, optimum temperature (20 – 39°C) enhances spawning of fish and the maximum temperature hardly exceeds the upper limit and

v. African magur (*Clarias gariepinus*), Piranha (*Pygocentrus nattereri*) and other exotic carnivorous species should not be attempted to be cultured in the *haor* ponds. Besides, Roho labeo (*Labeo rohita*), Catla (*Catla catla*), Mrigel carp (*Cirrhinus cirrhosus*), Orange fin labeo (*Labeo calbasu*), Tilapia (*O. mossambicus*), Striped catfish (*Mystus tengara*) and Pabda catfish (*Ompok pabda*) are the popular environmental friendly fish species that can be cultured in *haor* ponds.

3.6.5. Summary of Key Findings of the FGDs

Summary of key findings of the FGDs are presented below:

1. Due to fish culture in the *haor* pond, the income of local fish farmers has increased, employment has been generated for both male and female members of the households, nutrition intake has increased, some fish-centered business have been generated etc.;
2. Financial support for digging and raising the dikes of the pond should be arranged and aquaculture training should be imparted;
3. Fish sanctuaries are to be established and this measure is the best for preventing extinction of different varieties of local fish and increase production in general and
4. Frequency of the early flood/flash flood was has increased in the *Haor* area and the perceived causes include onrush of water from the Indian hills, excessive rainfall and disruption of link with the local rivers.

4. CONCLUSIONS

The study has provided evidence that *haor* pond aquaculture approach aimed at improving the lot of the poor and vulnerable is effective in the study area. The intervention has resulted in the improvement of

yield from ponds and generated higher income and nutritious food for the fish farmers. Existing cultural practices could support experimentation and learning under future initiatives in the *haor* area. Pond fishery in the *haor* area mainly has an income-generating feature and less probability of being affected by climate change impacts on culture fishery. The approach should be extended beyond study areas and be adopted as a key strategy for development of *haor* fisheries resources in Bangladesh.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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451 Annexure 1. The taxonomic group used in the catch analysis of the pond fishery & taxa contributed to
452 each group (Native cultured fish, Exotic cultured fish & natural non-cultured fish) by % to the catches.

Group	Scientific name	Local name	Common name	Percentage composition of the total					
				Netrakona	Sunamganj	Kishoreganj	Habiganj	B.Baria	Overall %
Native cultured Fish	*Labeo rohita*	Rui	Roho labeo	15.5	7.88	12.95	9.67	11.56	10.82
	Chrrhinus cirrhosus	Mrigal	Mrigal carp	5.95	3.48	3.42	8.33	7.56	5.29
	Catlacatla	Catla	Catla	5.31	0.91	2.67	3.33	5.81	3.23
	Amblypharyngodon mola	Mola	Indian carplet	1.53	2.88	0.48	2.78	0.21	1.66
	Labeocalbasu	Kaliboush	Orangefin labeo	-	-	0.62	-	0.71	0.27
	Mystussp.	Tengra	Striped catfish	0.4	-	-	-	0.53	0.19
	Ompok pabda	Pabda	Pabdah catfish	1.06	-	-	-	-	0.15
Exotic cultured Fish	*Oreochromis mossambicus*	Tilapia	Mozambique tilapia	1.62	28.18	4.52	43.33	12.62	18.49
	Oreochromis niloticus	Mono-sex tilapia	Nile tilapia	40.41	4.09	40.57	-	12.83	16.59
	Hypophthalmichthys molitrix	Silver carp	Silver carp	9.68	7.88	10.47	6.11	14.26	9.9
	Cyprinus carpio	Common carp	Common carp	4.02	13.64	4.74	2.22	6.07	7.94
	Barbonymus gonionotus	Thai sarputi	Thai sarputi	4.74	11.82	2.88	12.78	1.99	7.15
	Ctenopharyngodon idella	Grass carp	Grass carp	2.24	10.3	2.97	4.78	2.88	5.68
	Pangasianodonhypophthalmus	Thai pangus	Thai pangus	-	3.18	0.38	-	1.68	1.62
Natural non-cultured fish	*Puntius sp.*	Puti	Barb	2.88		2.72		4.28	1.86
	Channa striata/C. marulius	Shol/Gozar	Striped/ Great snakehead	0.87	2.27	1.82		1.37	1.56
	Heteropneustes fossilis	Shing	Stinging catfish	1.08		1.6			1.07
	Clarias batrachus	Magur	Magur	0.47		1.2			0.37
	Channa punctata	Taki	Spotted snakehead	2.13		0.61			0.63
	Anabas testudineus	Koi	Climbing perch	0.08		0.67			0.59
	Mastacembelus sp.	Baim	Eel	-		-		0.11	0.03
	Wallago attu	Boal	Wallago	-		-		0.08	0.02
	Palaemon sp.	Prawn	Prawn	0.05		0.41			0.07
		Local small fish	Loach, small catfish, eel, garfish	-		0.46		-	0.07
		Others	small barb, catfish, flying barb,	-	2.88	3.85	6.67	10.02	4.72

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