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The Community-based Fish Culture in Seasonal Floodplains and Irrigation Systems (CBFC) project is a five year research project supported by the Challenge Program on Water and Food (CPWF), with the aim of increasing productivity of seasonally occurring water bodies through aquaculture. The project has been implemented in Bangladesh, Cambodia, China, Mali and Vietnam, where technical and institutional options for community based aquaculture have been tested. The project began in 2005 and was completed in March 2010.

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Impacts of technological interventions on fish production and biodiversity of seasonal floodplains in Bangladesh

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Abstract

Six seasonal floodplains two in each basins across the three mighty river of Bangladesh viz., the Padma, the Teesta and the Brahmaputra located at Rajshahi, Rangpur and Mymensingh districts of Bangladesh were included in the study. The area of the floodplains under the study was 32 ± 13 ha and the period of study was for two years from 2007 to 2008. The objective of the study was to determine the impacts of technological interventions in the floodplains on fish yield and biodiversity benefiting the poor fisher folk and other community people. Technological interventions for fish culture in the floodplains included (a) the installation of low-cost large meshed bamboo fencing at water inlet and outlet points, and setting of ring culverts for maintaining suitable levels of water for fish culture without hampering the production of rice in the upland areas of the floodplains (b) stocking of larger fingerlings at suitable stocking densities of endemic (rohu, catla, mrigal) and exotic (silver carp, bighead carp, common carp/mirror carp) species at 31-48 kg/ha (c) post stocking management; use of extra fencing during over flooding and mobile guarding using boats (d) harvesting management; regulations in harvest for certain period, use of multiple harvesting techniques. These interventions were carried out through CB participation with initial technological and financial support from the Challenge Program Project (CP35).

Technological intervention from the project had a positive effect in enhancing the standing crop and biodiversity of non-stocked species of fishes in the floodplains. In the floodplains the abundance of non-stocked species of fish increased by 15 ± 6% as compared to the abundance before project intervention. The mean fish production in the floodplains increased to 443 kg/ha against baseline production of 124 kg/ha over a culture period of 5-6 months in a year with subsequent increase in period of employment of fishers, income and household fish consumption. Fish larvae, hatchlings and young fry of wild non-stocked fishes entered into the seasonal floodplains through large fence spacing. The restriction of fishing for certain period and undisturbed habitat, guarding of the floodplains contributed to higher productivity and enhancement of fish biodiversity in the seasonal floodplains.

Introduction

Bangladesh is a huge delta formed by three main river systems- the Padma (Ganges), Meghna and Jamuna-Brahmaputra and their tributaries (Map of Bangladesh showing the three mighty river system). There are 5.2 million ha of floodplain areas in the Indo-Gangetic river basin of which 2.8 million ha are located in Bangladesh. More than one-third of the lands in Bangladesh remain under water every year during monsoon to some extent are use as habitat for different species of fish. Inundated floodplains are rich in nutrients and natural fish food, and thus are excellent feeding, breeding and nursery grounds for fish and other aquatic organisms (**De Graff, 2003; De Graff and Marttin, 2003**). In 2007-08, the contribution of floodplains in Bangladesh to total fish production from inland open waters is 77% (**DoF, 2009**). About 6.7 million people are getting direct benefits for their food security and livelihoods gains from the floodplains in Bangladesh (**Dey and Prein, 2006**).

Bangladesh has rich in aquatic fish biodiversity with 260 freshwater fish species where minnows, catfish, eels, perch, gobies, clupeids and prawns constituted the major portion (**DoF, 2009**). A rich diversity of fish fauna is contributing significantly to the ecology and sustainable productivity of the floodplains. **Barr *et al* (2004)** reported that during the monsoon the floodplains of Bangladesh become integrated into a single biological productive system. About 20-30 fish species which are resident in the floodplains and tolerant of low levels of oxygen provided the majority of the national freshwater fish production.

The degradation of floodplains resulting from human interferences due to construction of roads, embankments, deforestation, encroachment for agricultural production, indiscriminate use of pesticides and natural causes (siltation, drought, cyclone and intrusion of saline water) has had negative impacts on fish diversity in Bangladesh. On the other hand, the indiscriminant use of different fishing gears, harmful techniques of fishing threatens the biodiversity of the seasonal floodplains. **Mostafa et al (2009)** reported that in 'Chalan Beel' floodplains located in the Padma and Jamuna river basins serves the livelihoods of about 5 million people having the habitats of 114 different species of fish where 19 species earlier abundant are now threatened. The annual fish production in 2005-06 from the floodplain was 12,217 tons which was half in amount than the production observed in 1982.

The study was carried to determine the impacts of technological interventions in the floodplains on the fish yield and biodiversity for livelihood of the community people with emphasis on poor

fisher folk. The technological interventions include: installation of low-cost large meshed bamboo fencing at water inlet and outlet points, and setting of ring culverts for maintaining suitable levels of water for fish culture without hampering the production of rice in the upland areas of the floodplains; stocking of larger fingerlings at suitable stocking densities of endemic and exotic carps; post- stocking management using extra fencing during over flooding and mobile guarding using boats and harvesting management which included regulations in harvest for certain period, use of multiple harvesting techniques. These interventions were carried out through CB participation with initial technological and financial support from the CP35 project.

Thus the objective of the study was undertaken to assess the impact of technological interventions on fish yields, biodiversity of non-stocked fish species for livelihood gains of community people including the poor fishers in three seasonal floodplains located in three different river basins in Bangladesh. The study aims to fill gaps in our understanding in improvement of fish yields, enhancement of fish biodiversity and its implications for diversified use of seasonal floodplains.

Materials and Methods

Study area and duration of the study

The study was conducted in three seasonal floodplains; Beel Mail, Angrar Beel and Kalmina Beel located in the river basins of the Padma, Teesta and Brahmaputra in the northwest and northern region of Bangladesh (Figure 1 and Table 1).

Table 1. Description of the floodplains selected for the studies from three river basins of Bangladesh.

Floodplain	River Basin	Location	Area (ha)	Ownership/Access	Mode of intervention
Beel Mail	Padma	Mohanpur, Rajshahi	40	15.2 ha public land and 24.8 private lands, leased out by Govt to Fisheries Society on 3 yrs interval. Rice production in private lands during dry months and fish production in monsoon	Started fish culture by setting bamboo fencing and by stocking fingerlings from 2005, from 2006 CP35 project supported through establishment of CB fish culture approach to fishers who leased the floodplain.

Kalmina Beel	Brahmaputra	Fulbaria, Mymensingh	33	33 ha private lands, during dry months were under rice production, open access during monsoon before project intervention	Started fish culture during monsoon under CB approach under the CP35 project from 2007 and continued
Angrar Beel	Teesta	Pirganj, Rangpur	31	31 ha private lands, rice cultivation during dry months, open access to fisheries before project intervention	Started fish culture during monsoon under CB fish culture approach in 2007, in 2008 it discontinued and later initiatives were taken to establish CB fish culture approach.

The above seasonal floodplains were under arrangement of collective management by the respective community based organizations (CBOs) with support from the Department of Fisheries (DoF) at Upazila and District levels. Researchers from the WorldFish Center and Bangladesh Agricultural Research Council also provided support and conduct the studies. The research was conducted from for a period of two years from January 2006 to December 2008.

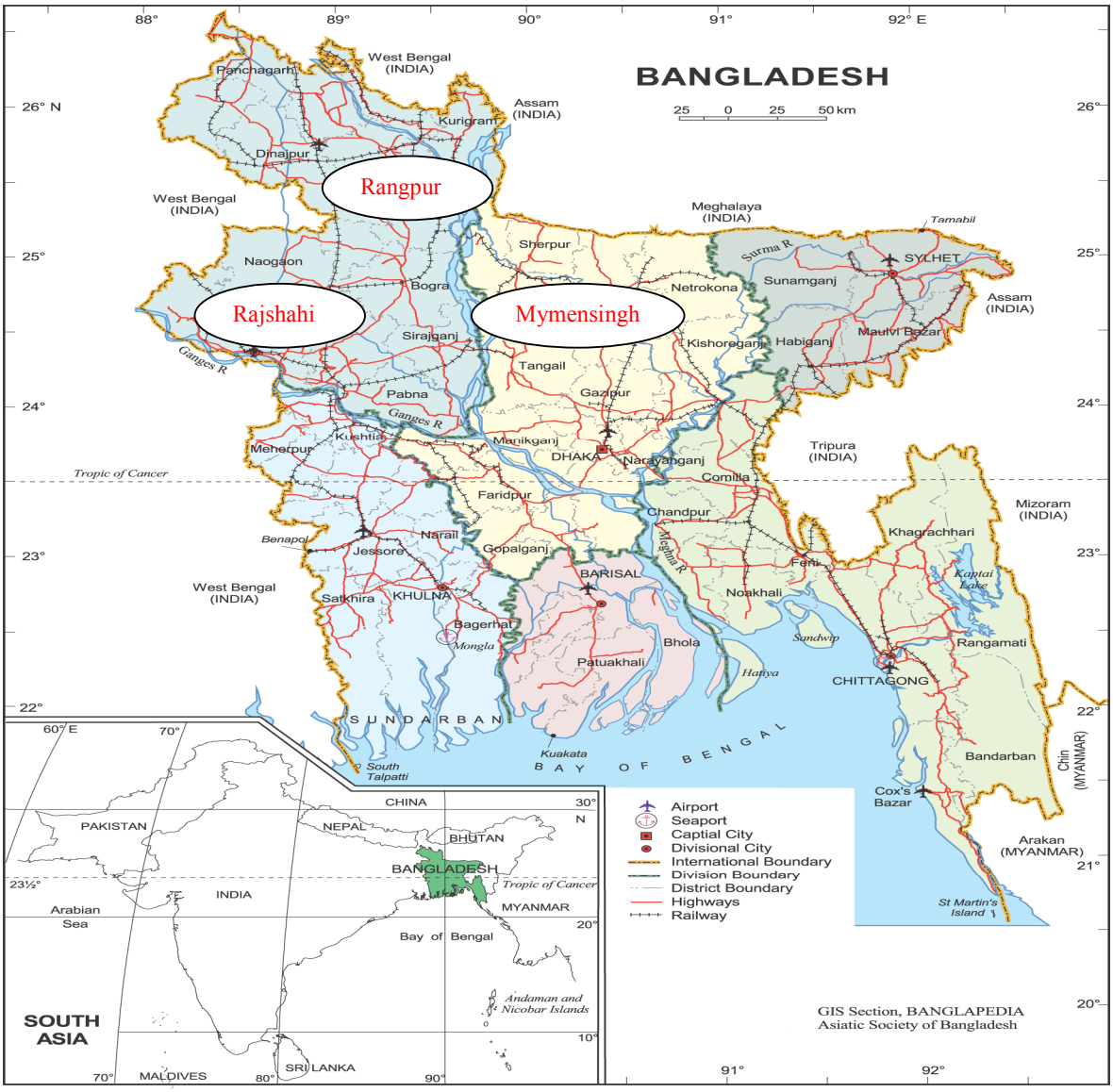

Figure 1. Location of the study area shown in the map of Bangladesh

Community Based arrangement for implementation and collection of information

The people living in the neighborhood of the floodplains under intervention, the professional fishers, landless people and landowners were identified. For CB management two committees the Floodplain Management Committee (FMC) and the Project Implementation Committee (PIC) were formed. These committees were working for planning, budgeting, implementation of fish culture activities and distribution of the benefits among members of the floodplains. The FMC was formed with representative from the communities however; the PIC in addition to representatives of FMC included government officials from the local Upazila and district level.

Baseline data on fish species and production in the sites before intervention collected to compare the effects of the technological interventions on biodiversity ("before vs. after"). The information regarding qualitative and quantitative aspects of fish catch and abundance of non-stocked fish species in sites were collected from the people in concerned local community. Focus Group Discussion (FGD) and Key Informant interviews methods followed by structured questionnaire survey were used in the information collection. The activities for collection of information included:

- Survey of the floodplains - to identify the inlet and outlets, measure the volume, location areas with seasonal water availability, deeper part of the floodplain, historical background etc)
- Existing management of the floodplains - leasing arrangement, investment, stocking and production and harvesting management)
- Information about the local institutions and experience of DoF experience about the floodplains
- Arrangement for intervention - fencing, water control outlets and inlets, stocking strategy, post-stocking management, harvesting and benefit sharing strategies
- Arrangement for data collection - involve one research enumerator for full time, frequent visit to the sites by the researcher, occasional visits and necessary advice by the supervisors

Technological intervention:

1. Installation of low-cost large meshed bamboo fencing at water inlet and outlet points, and setting of ring culverts for maintaining suitable levels of water for fish culture without hampering the production of rice in the upland areas of the floodplains:

The Bamboo poles were locally purchased by the beneficiaries, cut into pieces, usually 1.5 - 2.0 meters in length and splitted into slates of about 2.0 cm in width. The bamboo slates were joined together by means of synthetic ropes like stitching of cloth; at the top, middle and bottom portion of the bamboo slates. The mesh sizes of the bamboo fences were 1.0 cm. Thereafter, the fences were installed at the mouth of the inlets and outlets of water body in such a way that would permit the entry of larvae and hatchling of small indigenous species but prevented the stocked fish from being escaping. The fences were reinforced by fixing additional bamboo slates diagonally across the fence. A good number of bamboo poles, which served as stronghold to keep the fence in position, were fixed at the bottom of the

inlet-outlet at 1.0 meter distances in the close proximity of inlets and outlets. In some cases, the peripheral dikes of the water bodies were also raised to certain extent for holding water as well as preventing the escape of stocked fishes.

Several ring culverts comprising of ring concrete culvert (RCC) pipes with round holes of 60cm in diameter were installed at 0.3 meter above the bottom level of the floodplain and the upper side of the culverts were covered with soil for about 0.6 meter to maintain the water level and prolong the water retention time for Kalmina Beel floodplain. Further, the bamboo fences were fixed at the inlet and outlet of the other two sites of the Kalmina Beel floodplain. Besides use of bamboo fences in Beel Mail floodplain, the existing sluice gates constructed by WAPDA was regulated for retaining water throughout the culture period and draining out water for final harvesting of fish and also for facilitating the planting of winter rice. The three inlets and outlets of Angrar Beel Floodplain were also fenced like other floodplains. Earthwork was done to raise the embankment of the respective floodplains. The beneficiaries as well as hired labors were involved in repairing and elevating the level of the dike of the floodplains. .

2. Stocking of larger fingerlings at suitable stocking densities of endemic (rohu, catla, mrigal) and exotic (silver carp, bighead carp, common carp/mirror carps) carps at 31-48 kg/ha: The species combinations, ratios and stocking densities of fish fingerlings for stocking in the floodplains were determined based on factors such as local availability of fingerlings, the growth rates of the fish species and the experience of the people. The record about the species of fish fingerling stocked, the stocking density, the duration of the rearing of the fish stocked, the growth of the fish (total length, standard length and weight for individual fish of the sample) at the time of stocking and harvest were collected. The catch composition of fish species in the floodplains was recorded on daily basis using structured format. The format contained the local name, common name, scientific name and catch weight of the respective species. The number of fish species served as qualitative estimate of the biodiversity of fish population, while the catch weight of fish offered a quantitative indicator of species biomass also related to the biodiversity. The fishes were sorted and identified up to species level as guided by **Kapoor et al., 2002 and Rahman, 2005**. Qualitative and quantitative data were collected for stocked and non-stocked fishes.

3. Post stocking management; use of extra fencing during over flooding and mobile guarding using boats

4. Harvesting management; regulations in harvest for certain period, use of multiple harvesting techniques

Data processing and analysis

The impacts of stocking on fish production and biodiversity of non-stocked species in the seasonal floodplains were determined using comparisons before and after intervention, based on survey data. The comparisons were presented in tabular form. SPSS were used for data analysis.

Results

Species composition

The fishes recorded before and after the project intervention in the seasonal floodplains under the studies are categorized into the following 11 major groups (Table 2)

Table 2. List of major groups of fish species collected from the floodplains under fish culture

Major group	Scientific name	Beel Mail		Kalmina Beel		Angrar Beel	
		Before	After	Before	After	Before	After
1. Major carps	*1. Catla catla**	+	+	+	+	+	+
	*2. Labeo rohita**	+	+	+	+	+	+
	*3. Cirrhina mrigala**	+	+	-	+	-	-
2. Exotic carps	*4. H. molitrix**	+	-	-	+	+	+
	*5. Aristichthys nobilis**	+	+	-	+	+	+
	*6. Cyprinus carpio**	+	+	+	+	+	+
3. Catfish	*Aoricthys aor*	+	+	-	-	+	+
	Aorichthys	+	+	-	-	-	-
	Wallago attu	+	+	-	-	+	+
	Mystus tengra	+	+	+	+	+	+
	Clarias batracus	+	+	+	+	+	+
	Heteropneustus fossilis	+	+	+	+	+	+
	Ompok pabda	-	+	-	+	-	+
	Ailia coilia	-	+	-	+	-	-
4. Minnows and clupeid	*Amblypharyngodon mola*	+	+	+	+	+	+
	Gadusia chapra	+	+	-	-	-	-
	Mugil cascasia,	+	+	-	-	+	+
	Corica soborna	+	+	-	-	-	+
	Chela phulo	-	+	+	+	+	+
	Rasbora danicorias	+	+	+	+	+	+
	Botia Dario	+	+	+	+	+	+
5. Barb	*Barbus stigma*	+	+	+	+	+	+
	Barbus ticto	+	+	-	-	-	-

6. Perch and goramy	*Anabus testudineus*	+	+	+	+	+	+
	Nanduis nandus	+	+	+	+	-	-
	Colisha fasiata	+	+	+	+	+	+
	Colisha chuno	+	+	-	-	-	-
7. Murrels	*Channa striatus*	+	+	+	+	+	+
	Channa punctatus	+	+	+	+	+	+
	Channa gachua	-	+	-	+	-	-
8. Glassfish	*Chanda ranga*	+	+	+	+	+	+
	Chanda nama	+	+	-	-	-	-
9. Gobies	*Glossogobius giuris*	+	+	+	+	+	+
	Lepidicephalus guntea	+	+	+	+	+	+
10. Eel	*Mestacembelus panclas*	+	+	+	+	+	+
	Mestacembelus armatus	+	+	+	+	+	+
11. Small prawn	*Macrobrachium sp*	+	+	+	+	+	+
12. Miscellaneous	*Xenetodon cancilia*	+	+	+	+	+	+
	Tetredon cutcutia	-	+	-	+	+	+
	Notopterus notopterus	+	+	+	+	+	+
	Notopterus chitala	+	+	-	-	-	-
Total number of non-stocked species:		30	35	21	25	24	26
Increase in species abundance (%)		**16.66**		**19.04**		**8.33**	

+ indicates presence and – indicates absence of a particular species* fish species stocked in the floodplains

Fish biodiversity of the floodplains not affected negatively due to intervention of fish culture under community based system. Before intervention 30 species of non-stocked fishes were identified in Beel Mail, 21 species in Kalmina Beel and 24 species in Angrar Beel. After implementation of the technical intervention the, number of non-stocked fish species in each beels showed 8-19% increase over the initial base level populations (Table 2).

Fish biomass

There was significant increase in both stocked and non-stocked species biomass after implementation of technical interventions (Table 3). Before technical interventions, non-stocked fish production in Beel mail floodplain, Kalmina beel floodplain and Angrar beel floodplain were recorded to be 175 kg/ha/yr, 46 kg/ha/yr and 43 kg/ha/yr, respectively; while these values stood at 293 kg /ha/yr, 58 kg/ha/yr and 43 kg/ha/yr after project intervention.

Table 3. Fish biomass (kg/ha/yr) both stocked and non-stocked in the selected seasonal floodplains before and after the technical interventions

Floodplain	Before intervention (kg/ha/yr)			After intervention (kg/ha/yr)		
	Stocked fish	Non-stocked fish	Total	Stocked fish	Non-stocked fish	Total
Beel Mail	107	175	282	365	293	658
Kalmina Beel	0	43	43	230	58	288
Angrar Beel	0	46	46	172	43	215

Production of stocked fish (native and exotic carps) exhibited pronounced increase from their base level after technical interventions were exercised in the floodplains. Per hectare average production of stocked fishes were 365 kg/ha/yr, 230 kg/ha/yr and 172 kg/ha/yr in Beel Mail floodplain, Kalmina beel floodplain and Angrar beel floodplain, respectively after project intervention. Average total fish production (both stocked and non-stocked) in these seasonal floodplains were 658 kg/ha/yr, 288 kg/ha/yr and 215 kg /ha/yr following technical interventions
(Table 4).

Table 4. Fish biomass (kg/ha/yr) with number of species in the selected seasonal floodplains before and after the technical interventions

Floodplain	Before Intervention (kg/ha/yr) (# of species)	After intervention (kg/ha/yr) (# of species)	Changes (kg/ha/yr) (%)
Beel Mail	**282 (36)**	**658 (40)**	**+376 (233)**
Kalmina Beel	**46 (24)**	**288 (30)**	**+242 (627)**
Angrar Beel	**43 (29)**	**215 (31)**	**+172 (499)**

Contribution of major groups of fishes

The contribution of different groups of fishes to the total fishery yield is presented in Table 5. It is evident that exotic carps contributed the bulk of the fishery production in all the experimental seasonal floodplains, followed by native carps. Among the non-stocked species, the barbs, catfishes, minnows and clupeids, glassfish, and small prawns were the most dominant fauna in most of the seasonal floodplains.

Table 5. Biomass of major groups of fishes harvested from Beel Mail Floodplain before and after fish culture under CB fish culture

Major groups of fish	Bell Mail			Kalmina Beel			Angrar Beel		
	Biomass (kg/ha)			Biomass (kg/ha)			Biomass (kg/ha)		
	Before	After	Change	Before	After	Change			
1Exotic carps	75	308	+233	1	166	+165	2	92	+90
2 Major Carps	32	57	+25	1	64	+63	3	80	+77
3 Minnows and clupeid	43	79	+36	5	7	+2	6	6	+0
4 Catfish	36	48	+12	1	2	+1	7	7	+0
5 Glassfish	20	45	+25	3	6	+3	2	3	+1
6 Barb	28	41	+13	13	18	+5	9	8	-1
7 Gobies	15	18	+3	0.48	2	+1.52	0.7	2	+1..3
8 Murrels	15	19	+4	1	1	+0	1	2	+1
9 Small prawn	11	25	+14	18	19	+1	11	12	+1
10 Perches	1	3	+2	0.30	1	+0.7	0.3	0.9	+0.6
11Eels	2	6	+4	2	2	+0	1	2	+1
12 Miscellaneous fishes	4	9	+5	0.12	0.37	+0.25	0.11	0.52	+0.41
Total	**282**	**658**	**+376**	**46.00**	**288.37**	**+242.47**	**43.11**	**215.42**	**+172.31**

Impact of technological intervention on species shift

Data contained in table 3 indicated that technological intervention, particularly fencing of the seasonal floodplains with restricted fishing increased the biomass of non-stocked species in the experimental seasonal floodplains. Abundance of all non-stocked species except catfishes and murrels showed increases from their baseline levels (before technological intervention). Among the catfishes, *Wallago attu* and *Aorichthyes aor* exhibited decreasing trends after technological intervention in Beel Mail floodplain. The reduced biomass of *Wallago attu* and

Aorichthyes aor appeared to be due to fencing which limited their entry to the floodplain. Onset of earlier spawning and rapid growth of these species made them too big to pass through the mesh size of the fence though they had initial access to the beel through the bana fence. The population of murrels (*Chana striatus*) also dwindled in Beel Mail floodplain after technological intervention.. The reason for reduced biomass for *Chana striatus* seemed to be due to its inability to enter into the beel through the bana fencing and failure to breed there. From the pooled catch data it can be concluded that technological intervention significantly increased the fish biomass of non-stocked species in the experimental seasonal floodplains in comparison to base line data. Fish biodiversity also increased in the experimental seasonal floodplains after intervention in comparison to their respective control floodplains.

Discussion

Technological interventions involving fencing of the seasonal floodplains along with raising of dykes followed by stocking of native and exotic carps was very effective in increasing the biomass of both non-stocked and stocked fish over a six-month production cycle. Fish biodiversity of the experimental seasonal floodplains also increased as a result of the intervention. Both qualitative and quantitative increases in the abundance of stocked and non-stocked species of fishes were clearly demonstrated. The rapid increase in the fish yield of stocked species can be attributed to inclusion of fast growing exotic carps such as bighead carp, silver carp and common carp. Of the native carps, *Catla catla* and *Cirrhinus mrigala* contributed moderately to the fishery yield. On the other hand, growth performance of Rohu (*Labeo rohita*) was rather discouraging in some of the selected beels..

Technological intervention was found to be very conducive in enhancing the biodiversity of the wild fishes. **Dey and Prein (2005)** reported that stocking of carps with fencing promotes the biodiversity of non-stocked fishes in seasonal floodplains. Increased availability of the wild species of fishes in the experimental seasonal floodplains could be attributed to easy entry of larvae, hatchlings and juvenile fishes to the concerned floodplains through the spacing between the bamboo slates of the fences. Absence of large predatory fishes, undisturbed habitat, restricted fishing activities and guarding of the fenced beels facilitated the migratory fishes to settle, feed and grow without disturbances.. Increased fish biodiversity in Beel Mail floodplains can be attributed to migration of wild fishes from the nearby fish sanctuary and surrounding beels. Further, occurrence of two flood occasions in 2007 facilitated the large scale movement of escaped fishes and their entry into the Beel Mail

seasonal floodplains. The lower level of species diversity and comparatively low biomass in the studied seasonal floodplains before intervention is presumed to be due to high exploitation rate and non-selective gear use of fishes by the fishers..

Elevation of bottom part of the inlets/ outlets by earth filling and installation of ring culverts prolonged the water retention time in the respective floodplains which also contributed to increased biodiversity and fish biomass.

The clupeid (*Gadusia chapra*), barbs (*Barbus* spp), catfishes and small prawns(*Macrobrachium* spp) were the dominant groups in the catch and accounted for the bulk of fish biomass in Beel Mail seasonal floodplain. **Hossain *et al* (2000)** observed high abundance of barbs (*Barbus* spp) in three seasonal floodplains in central and north-west part of Bangladesh. The increased abundance of large numbers of fish species in seasonal floodplains of Beel mail is largely due to its connectivity with the Padma river basin through Barnai river. This beel is also well connected with other local beels which link with Barnai river.

The high abundance of clupeids and barbs in different seasonal floodplains appeared to be related with their prolific breeding characteristics and rapid growth rate. The similar phenomenon was also observed by **Haque *et al*. (1999)** in oxbow lakes in south-west Bangladesh.

Conclusion and recommendations

Technological interventions had significant beneficial effect on fish production in the selected seasonal floodplains. A pronounced increase in fish production was clearly demonstrated in the stocked beels concurrent with increase in the abundance of non-stocked forage fishes. Technological interventions enhanced the biodiversity of non-stocked fish species in terms of both quality and quantity. Further studies should be conducted to determine the efficacy of various technological options to maximize fish production in seasonal floodplains in different locations of Bangladesh under different river basins. Further research should be conducted on development of techno-socio-economic models for ecologically sound management of the seasonal floodplains with the objectives of fish biodiversity enhancement and improved food security of the local communities dependent on these resources.

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