Conserving nutrient rich small indigenous species of fish in the wetlands of north-eastern Bangladesh

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Abstract. Small Indigenous Species (SIS) of fish played an important role in the Bangladeshi diet but biodiversity of these species in natural wetlands has alarmingly decreased. Therefore, an initiative was taken by WorldFish for the enhancement of a nutrient rich SIS mola (*Amblypharyngodon mola*) production in some wetlands of Sunamganj in Bangladesh. In continuation of the work, present study was conducted with randomly selected four stocked beels and one non-stocked beel to assess the impact of stocking of mola. Catch data were collected directly by using semi-structured questionnaires. Results showed that mean annual mola productivity was significantly increased (from 6.19 ± 6.51 $kgha^{-1}year^{-1}$ to 85.21 ± 56.08 $kgha^{-1}year^{-1}$) in four stocked beels. Mean annual fish production also showed significantly higher than baseline year. Notably, the growth rate of increasing productivity was more than 7 times greater in stocked beels (66.84%) than non-stocked beel (9.24%). The average value of diversity index of stocked wetlands was also increased from 2.92 ± 0.49 to 2.97 ± 0.48 in the baseline and final year, respectively. Stocking of SIS in the wetlands including establishment of sanctuary with proper management might stimulate to increase biodiversity and production of fishes.

Key Words: mola, beel, biodiversity, production, management.

Introduction. Bangladesh is a uniquely rich and blessed country with a diverse fisheries resource base and several naturally productive wetlands (Kibria & Ahmed 2005). These wetlands support around 260 species of freshwater fishes and about 60% animal protein of Bangladeshi daily meals comes from these resources (DoF 2018). As a result, fish and fisheries have long been a part of Bangladeshi culture, and they continue to play an important role in providing nutritional needs, creating employment, earning foreign currency, and other sectors of the economy (Alam 2002).

In Bangladesh, Small Indigenous Species (SIS) of fish (length<25cm) is a native, self-recruiting, tasty and a source of vital micronutrients such as calcium, vitamin A, phosphorus, and iron (Hossain et al 1999). Some decades ago, water bodies were enriched with SIS such as mola (*Amblypharyngodon mola*), chapila (*Gudusia chapra*), chela (*Chela cachius*), darkina (*Esomus danricus*), dhela (*Osteobrama cotio*), and rani (*Botia dario*) which have been recognized as nutritionally enriched fish species (Bogard et al 2015). These species are the rural poor's favorite food items (in comparison to large fish) and are usually prepared, cooked, and eaten whole body (Thilsted & Roos 1999). Among them, mola is very demandable to the people due to its unique taste and high amount of valuable micronutrient contents (Alam et al 2004; Saha et al 2009; Ahamed et al 2017). In this way, this species has become a vital species by acting as an essential source of income for many subsistence and artisanal fishermen (Talwar & Jhingran 1991; Jayaram 1999; Daniels 2002; Ahamed et al 2017). However, this fish is also a multi-breeder fish which breeds 2-3 times per year and fecundity is high (1000-8000 per year).

For this reason, mola was found in high numbers in rivers, canals, beels (shallow lakes which form in the lowest parts of the haor, which is a larger body of connected waters), streams and ponds before 1960 but is now disappearing day by day (Wahab 2003). Some manmade causes including indiscriminate fishing, overfishing, use of illegal destructive fishing gears, katha fishing (brush pile) which is a fish aggregating device that provides shelter for fish, attracting fish to congregate there for easier capture (Das et al 2022), reduction of water level due to irrigation, fishing by complete drying of beels and use of pesticides in agricultural fields and many natural causes are responsible for reducing mola and other fish diversity from natural aquatic habitats of Bangladesh (Pandit et al 2015a; Arefin et al 2018; Islam et al 2019). In these circumstances, enhancement of mola and other SIS in the natural water bodies is very important. Priority should be given in increasing public awareness to understand the significance of SIS (mola). Importance of co-management and transferring the knowledge of stocking of SIS in natural water bodies, establishment of sanctuary along with introduction of mola in pond aquaculture and rice-fish culture systems can increase its production in many folds.

The haor region of Bangladesh covers almost one fourth portion (25%) of the north-eastern Bangladesh, geographically located in the seven districts namely Sunamganj, Habiganj, Sylhet, Moulvibazar, Kishoreganj, Netrakona, and Brahmanbaria (Alam et al 2007, Pandit et al 2015a). The deepest part of this region is composed of perennial wetlands such as rivers and beels. During monsoon, beels are connected with all adjacent water bodies and look like a single water body which is called haor. However, the haor basin is a natural combination of wetland environments comprising interconnected beels, rivers, streams, seasonal floodplains, and irrigation canals (Hussain & Salam 2007; Pandit et al 2015b). Sunamganj Community Based Resource Management Project (SCBRMP) was implemented in the haor region of Sunamganj by Local Government Engineering Department (LGED) of Bangladesh funding from International Fund for Agricultural Development (IFAD). The fisheries part of the project was done with the technical support of WorldFish. WorldFish promoted this innovative new technology designed to increase the production of mola in open waterbodies in Sunamganj where 14 selective beels among 60 monitoring beels of WorldFish were included for mola enhancement activities (Mohsin & Khan 2014). The present study was conducted at 4 mola stocked beels (out of 14 beels) and 1 non-stocked beel to find out the impact of mola stocking on annual fish production and species diversity in the beels of Sunamganj district in Bangladesh.

Material and Method

Selection of study areas. The study was took place from April 2015 to March 2016 in the deeply flooded beels distributed in 3 upazilas (sub-districts) (Derai, Sunmaganj Sadar and South Sunamganj) of Sunamganj district in Bangladesh (Figure 1). Present study was a part of ongoing project implemented by WorldFish which was started with a baseline survey in 2012-13. In March-April 2013, 14 beels in the haor region of Sunamganj were randomly selected and nutrient rich small fish, mola was stocked under the working area of SCBRMP of WorldFish, Bangladesh (Mohsin & Khan 2014). However, out of 14 mola stocked beels present study was conducted at randomly selected 4 beels namely Mangolpurer Dubi beel, Juri Panjuri beel, Piranagar beel, Rajghori beel and 1 non-stocked beel (control) as Kachua beel (Table 1, Figure 1) to find out the impact of mola stocking on annual fish production and fish species diversity.

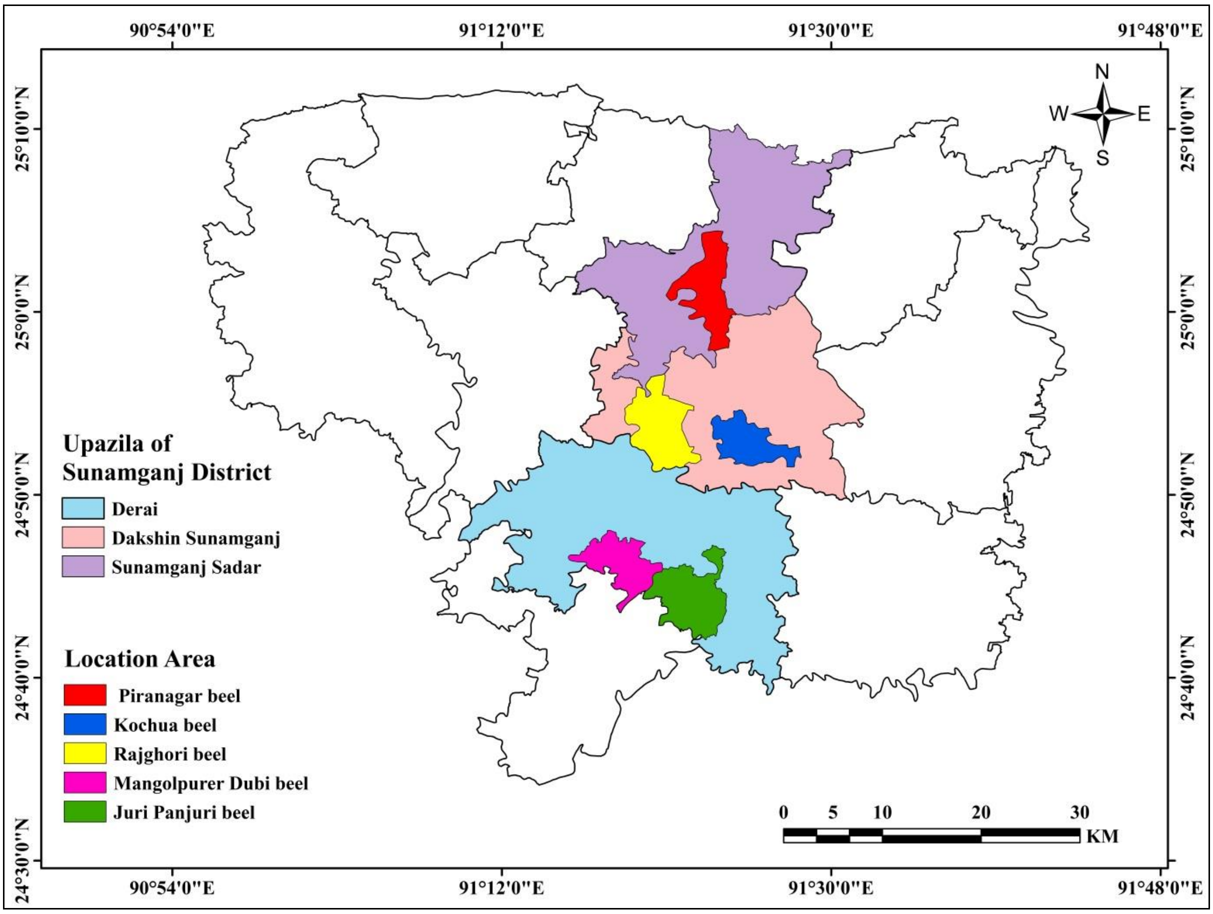

Figure 1. Map of Sunamganj district depicting the study areas (map generated using ArcGIS 10.5).

Stocking status of mola broods. Mola were collected from different areas and gathered in hired pond nearby the project area and reared for few days. Fish were then stocked in newly established sanctuary/katha (shelter and traditional fish aggregating device made of bamboo poles, tree branches, ropes etc.) in March-April 2013 so that mola can get predator free habitat for survival and self-recruitment. A total of 113.0 kg mola was stocked in 4 studied beels and no mola was stocked in the control beel (Table 1). Mola bred during April-June and the haor water gradually increased during this time, so that mola offspring spread all over the haor and grown up.

Table 1

Stocking density of mola brood in the selective beels (kg) in 2013

Name of the beels	*Name of the sub-district*	*Beel area (ha)*		*Amount stocked (kg)*	*Stocking density ($kgha^{-1}$)*
		Total area	*Water area during stocking*		
Mangolpurer Dubi beel	Derai	5.70	0.06	21.00	350.00
Juri Panjuri beel	Derai	23.16	0.08	14.50	181.25
Piranagar beel	Sunamganj Sadar	4.07	0.81	57.00	70.37
Rajghori beel	South Sunamganj	4.19	0.08	21.00	262.50
Kochua beel (control)	South Sunamganj	3.86	0.61	00.00	00.00

Awareness building for good management practices. During the project period, some awareness building activities were performed to motivate BUG (Beel User Group) members about the conservation of aquatic resources, causes of fisheries reduction in natural waterbodies, how to improve the fish production through community participation, importance of fish sanctuary and protection of fishes from illegal fishing. It was focused to protect fishes through providing security, setup signboards and how to build sanctuary using branches of trees, bamboos, broken boats, and concrete pole. The entire activities were done by the project staffs along with the support of local relevant administration.

Catch monitoring and biodiversity assessment. The study was conducted through direct catch assessment at the time of fishing by using semi-structured questionnaires. During the study period, data were grouped into two types such as organized catch during dry season (November to March) and open catch during flooded season (April to October). The fish species were sorted and identified based on their external morphological appearance (Talwar & Jhingran 1991; Rahman 2005; IUCN Bangladesh 2015).

Organized catch. At the end of open catch, organized catch was started either when the water started reducing or sometimes, they wait for getting good market price. Only BUG members had the access of fishing from the beels in this period. Generally organized catch starts in November and continues up to March of the next year. Date and time of organized catch is determined by BUG meeting and informed to the community enumerators of WorldFish. The number and weight of all captured fish species were recorded.

Open catch. Open catch data was collected simultaneously for eight days in a month when all fishers had the access of fishing in the beels including BUG members. The total number and weight of all captured fish species were taken and recorded. In the case of small fishes with high bulk weight, a small amount of fish (about 250–350 g) is weighed separately as a sample, then counted to get the number of individuals of each species in the sample, and finally calculated to get the total number of small fish of each species in the total catch.

Catch analysis. Fish production was calculated by the following formula:

$$\mathrm{CPUA} = \frac{\mathrm{Tc}}{\mathrm{Ta}} \quad \text{(i)}$$

Where, CPUA stands for the productivity or catch per unit area in $kg ha^{-1} year^{-1}$, Tc is the total catch of fish per year in kg, and Ta is the total area of each beel in ha.

To count the number of small fishes in the total catch, following formula was used:

$$N = \frac{Ns \times Wt}{\mathrm{Ws}} \quad \text{(ii)}$$

Where, N is the number of individual small fish in the total catch, Ns is the number of individual small fish in each sample, Wt is the total weight of small fish found, and Ws is the weight of each sample.

Data processing and analysis. The collected data was computed in Microsoft Access 2010 data base management tools. For comparison, baseline data of fish catch during 2012-2013 was taken from WorldFish. At the end of the experiment, all data was analyzed statistically using one way Analysis of Variance (ANOVA) to assess the significance of variations in fish catch from different wetlands. The software Statistical Package for the Social Sciences (SPSS) version 20.0 was used for all the analysis. Tables and figures were used for the presentation of results.

Shannon-Wiener biodiversity index. For determining the biodiversity or heterogeneity of species parity in a specific beel, Shannon-Wiener biodiversity index (H) was used (Shannon & Weaver 1949):

$$H = -\sum \mathrm{Pi} \ln \mathrm{Pi}$$

Where, H is the fish diversity index (Shannon-Wiener biodiversity index), Pi is the relative abundance of fishes (s/N), s is the number of available individuals for each species, N is total number of individuals of all species, and ln is the natural logarithm.

Results

Annual production of mola. The mean (±SD) value of annual mola production in the final year (2015-2016) was significantly higher ($P<0.05$) compared to the baseline year (2012-2013). Total mola production was estimated at 1794.91 kg with an average of 448.73±259.61 kg in which open catch and organized catch was 601.64 kg and 1193.27 kg, respectively from the 4 stocked beels. However, the highest mola production was found in Mongolpurer Dubi beel with 809.74 kg from both catches (open catch 341.82 kg and organized catch 467.92 kg) and the productivity was (142.06 $kgha^{-1}year^{-1}$), whereas lowest mola production beel was found in Juri Panjuri beel with 198.63 kg (Table 2). In 2012-2013 (baseline year), total mola production was assessed at 155.65 kg with an average of 38.91±33.29 kg where open catch and major catch contributed 126.52 kg and 29.13 kg, respectively. During baseline survey the highest productive beel for mola was Mongolpurer Dubi beel (82.56 kg) and lowest production was found in Rajghori beel (1.63 kg) where harvesting from organized catch was zero (Table 2).

Table 2

Annual production of mola from the stocked *beels* in the baseline and final year

Name of the beels	*Open catch (kg)*		*Organized catch (kg)*		*Annual production (kg)*	
	Baseline	*Final*	*Baseline*	*Final*	*Baseline*	*Final*
Mangolpurer Dubi *beel*	70.99	341.82	11.57	467.92	82.56	809.74
Juri Panjuri *beel*	33.39	146.26	4.57	52.37	37.96	198.63
Piranagar *beel*	20.51	61.92	12.99	291.60	33.5	353.52
Rajghori *beel*	1.63	51.64	0.00	381.38	1.63	433.02
Total production	126.52	601.64	29.13	1193.27	155.65	1794.91
Average (Mean ± SD)	31.63 ± 29.30	150.41 ± 134.46	7.28 ± 6.09	298.32 ± 179.07	38.91 ± 33.29	448.73 ± 259.61
Kochua beel (Control)	3.75	0.56	22.00	07.00	25.75	07.56

Mola production was significantly increased in both catches (open catch and major catch) in four mola stocked beels, whereas highly decreased in non-stocked beel (Kochua beel). In Kochua beel total mola production was 25.75 kg at the time of baseline study and finally mola production is decreased to 7.56 kg (Table 2, Figure 2).

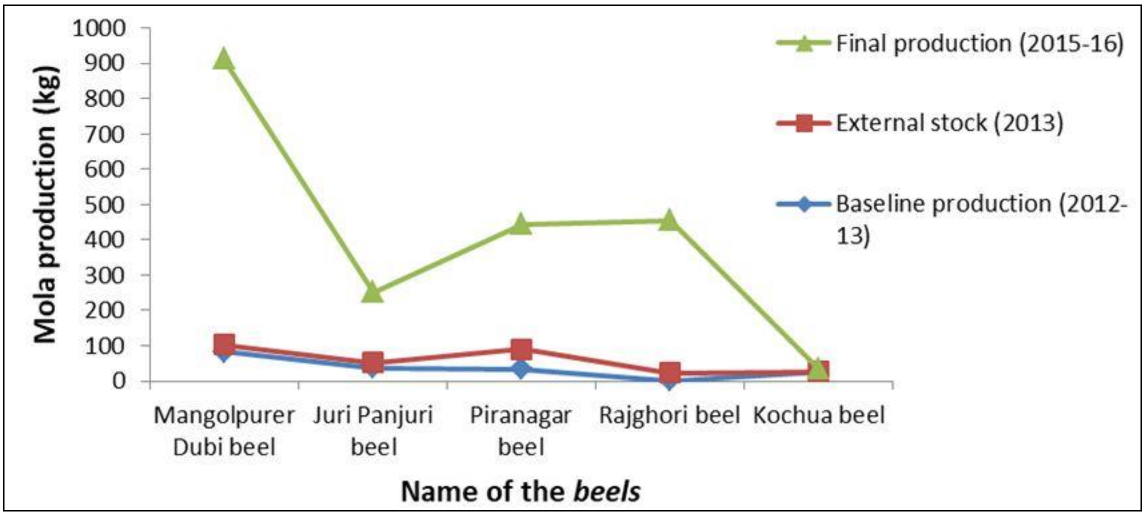

Figure 2. Comparison of mola production between 2012-2013 and 2015-2016.

Annual fish production. Due to mola stocking and community-based management practices by BUG a statistically significant change was made in total fish production ($p<0.05$). In the final year, total fish production was estimated at 27755.14 kg with an average of 6938.79±1251.17 kg from the project beels where open catch provided 18366.00 kg and major catch was 9389.14 kg. Among these beels, the highest harvest was recorded 8727.73 kg in Piranagar beel where open catch was 4945.59 kg and major catch was 3782.14 kg; lowest production was found 5807.59 kg in Rajghori beel where open catch was 3630.57 kg and major catch was 2177.02 kg (Table 3). In the baseline year, total fish production was estimated at 18078.57 kg with an average of 4519.64±1341.62 kg in which open catch and organized catch provided 10857.98 kg and 7220.59 kg, respectively from the project beels. The harvest from the open catch was higher comparing to the organized catch. The highest production was 5310.25 kg in Mongolpurer Dubi beel and lowest production 2520.19 kg recorded from Rajghori beel (Table 3).

Table 3

Annual fish production from the study area in the baseline and final year

Name of the beels	*Open catch (kg)*		*Organized catch (kg)*		*Total production (kg)*	
	Baseline	*Final*	*Baseline*	*Final*	*Baseline*	*Final*
Mangolpurer Dubi *beel*	3100.11	4183.66	2210.14	2429.98	5310.25	6613.64
Juri Panjuri *beel*	4329.67	5606.18	946.50	1000.00	5276.17	6606.18
Piranagar *beel*	2289.36	4945.59	2682.60	3782.14	4971.96	8727.73
Rajghori *beel*	1138.84	3630.57	1381.35	2177.02	2520.19	5807.59
Total production	10857.98	18366.00	7220.59	9389.14	18078.57	27755.14
Average (Mean ± SD)	2714.50± 1344.24	4591.50 ± 865.00	1805.15± 785.46	2347.29± 1141.61	4519.64± 1341.62	6938.79± 1251.17
Kochua beel (Control)	1573.62	1814.88	993.48	989.50	2567.10	2804.38

Impact of mola stocking on fish productivity (CPUA). Mola stocking had a significant effect ($p<0.05$) on fish productivity. In four mola stocked beels, the average fish productivity (CPUA) during the baseline year (2012-2013) was 745.63 kgha^{-1}year^{-1} which was increased significantly by almost 66.84% (1244.00 kgha^{-1}year^{-1}) by the 4th year (2015-2016) of the mola stocking. Growth rate of production was highest in the Rajghori beel (130.44%) followed by the Piranagar beel (75.54%), Juri Panjuri beel

(25.21%), and Mangolpurer Dubi beel (24.54%). Similarly, the fish productivity of non-stocked Kochua beel was also increased by 9.24% (from 665.05 kgha^{-1}year^{-1} to 726.52 kgha^{-1}year^{-1}) (Table 4, Figure 3). However, the average growth rate of increasing productivity was more than 7 times greater in the stocked beels than non-stocked beel.

Table 4

Beel wise CPUA of mola and total fish production from the study areas

Name of the beels	*CPUA (kgha^{-1}year^{-1}) of mola*		*CPUA (kgha^{-1}year^{-1}) of all fish*	
	2012-13	*2015-16*	*2012-13*	*2015-16*
Mangolpurer Dubi beel	14.48	142.06	931.62	1160.29
Juri Panjuri beel	1.64	8.58	227.81	285.24
Piranagar beel	8.23	86.86	1221.61	2144.41
Rajghori beel	0.39	103.35	601.48	1386.06
Average (mean ± SD)	6.19 ± 6.51	85.21 ± 56.08	745.63 ± 428.20	1244.00 ± 765.32
Kochua beel (control)	6.67	1.96	665.05	726.52

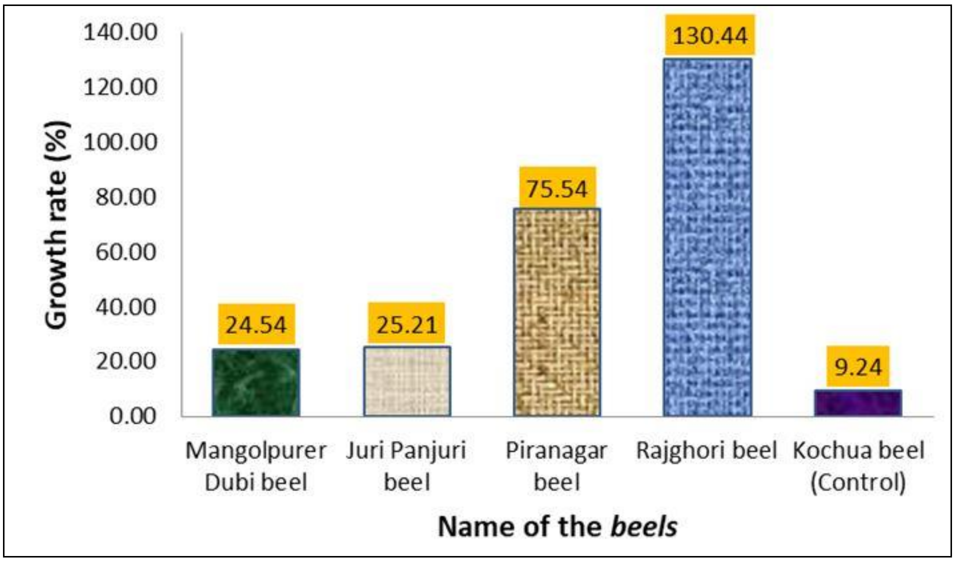

Figure 3. Growth rate (%) of fish production in the final impact year comparing baseline year.

Changes in the contribution of mola to annual fish production. In four stocked *beels*, mola contributed to 6.69% of the annual fish production of the beels in 2015-2016 but in baseline production contribution was only 0.75%. In the final year, contribution of mola to annual fish production was highest in the Mangolpurer Dubi beel (12.24%) and lowest in the Kochua beel (0.27%). During baseline, highest contribution (1.55%) recorded from the same beel but lowest was recorded from Rajghori beel (0.06%) (Table 5).

Table 5

Contribution of mola in production by percentage from total harvest

Name of the beels	*Contribution of mola to total production (%)*	
	Baseline	*Final*
Mangolpurer Dubi beel	1.55	12.24
Juri Panjuri beel	0.72	3.01
Piranagar beel	0.67	4.05
Rajghori beel	0.06	7.46
Average (mean ± SD)	0.75 ± 0.61	6.69 ± 4.16
Kochua beel (non-stocked)	1.00	0.27

Changes in fishermen income due to mola enhancement program. In the baseline year, total fish production from 4 mola stocked beels was 18078.57 kg from both open and organized catches whose market value was approximately US$ 28446.41 where mola contributed only US$ 230.31 from 155.65 kg mola. However, after stocking of mola and good management practices, total fish production was increased to 27755.14 kg and price approximative US$ 44553.44, where mola contributed US$ 2892.64 from 1794.91 kg (Table 6).

Table 6

Annual total fish production, mola production and total income

Year	*Total fish production including mola (kg)*	*Mola production (kg)*	*Income from total fish production (US$)*	*Income from mola production (US$)*
2012-2013	18078.57	155.65	28446.41	230.31
2015-2016	27755.14	1794.91	44553.44	2892.64
Growth rate (%)	154%	1180%	157%	1256%

Changes in fish species diversity of the wetlands. After stocking of mola, total number of documented species were 60, 57, 54, 52 and 41 in Mangolpurer Dubi beel, Juri Panjuri beel, Piranagar beel, Rajghori beel and Kochua beel, whereas baseline survey showed 58, 60, 52, 35 and 53 species, respectively (Table 7).

Table 7

Fish species diversity status of five studied beels

Scientific name of fish species	*Mangolpurer Dubi beel*		*Juri Panjuri beel*		*Piranagar beel*		*Rajghori beel*		*Kochua beel*	
	Baseline	*Final*	*Baseline*	*Final*	*Baseline*	*Final*	*Baseline*	*Final*	*Baseline*	*Final*
Amblypharyngodon mola	√	√	√	√	√	√	√	√	√	√
Anabas testudineus	√	√	√	√	√	√	√	√	√	√
Aplocheilus panchax	√	√	√				√	√		
Badis badis		√			√	√				
Barilius bendelisis						√				
Barilius tileo								√		√
Batasio batasio				√		√		√		√
Botia dario	√	√	√	√	√	√		√		
Botia dayi		√			√	√			√	
Catla catla	√	√	√	√	√	√		√		
Chanda lala	√	√	√	√	√	√	√	√	√	√
Chanda nama	√	√	√	√	√	√	√	√	√	√
Chanda ranga	√	√	√	√		√		√	√	√
Channa gachua			√					√		
Channa marulius	√	√	√	√	√	√	√	√	√	√
Channa orientalis	√		√	√				√	√	

Channa punctata	√	√	√	√	√	√	√	√	√	√
Channa striata	√	√	√	√	√	√	√	√	√	√
Chela cachius									√	
Cirrhinus cirrhosus	√	√		√		√		√		
Cirrhinus reba	√	√	√	√	√			√	√	√
Clarias batrachus	√	√		√		√	√	√	√	√
Colisa fasciatus	√	√	√	√	√	√	√	√	√	√
Colisa lalius	√	√	√	√	√	√	√	√	√	√
Colisa sota		√	√		√	√				
Corica soborna			√							
Crossochelius latius									√	
Ctenopharyngodon idella	√		√					√		
Ctenops nobilis			√							
Cyprinus carpio (specularis)	√	√	√	√	√	√		√	√	
Danio dangila									√	
Dermogenys pussilus					√					
Esomus danrica	√	√	√	√	√	√	√	√	√	√
Eutropiichthys vacha	√	√	√	√	√				√	
Gagata gagata									√	
Gagata youssoufi			√	√						
Glossogobius giuris	√	√	√	√	√	√	√	√	√	√
Gonialosa manminna			√	√						
Gudusia chapra	√	√	√	√	√	√	√	√	√	√
Hemiramphus gaimardi						√			√	
Heteropneustes fossilis	√	√	√	√	√	√	√	√	√	√
Hypophthalmichthys molitrix				√	√	√		√		
Labeo calbasu	√	√	√	√	√	√	√	√	√	√
Labeo gonius	√	√	√	√	√	√	√	√	√	
Labeo rohita	√	√	√	√		√	√	√	√	√
Lepidocephalichthys guntea	√	√	√	√	√		√	√	√	√
Macrobrachium villosimanus							√			
Macrobrachium lamarrei	√	√		√		√		√	√	√
Macrognathus aculeatus	√	√	√	√	√	√	√	√	√	√
Mastacembelus armatus	√	√	√	√	√	√	√	√	√	√
Mastacembelus pancalus	√	√	√	√		√	√	√	√	√
Mystus bleekeri	√	√	√	√	√	√	√	√		
Mystus cavasius	√	√	√	√					√	√
Mystus seenghala	√	√	√	√	√	√	√	√		√
Mystus tengara	√	√	√	√	√	√	√	√	√	√
Mystus vittatus	√	√	√	√	√	√	√	√	√	√
Nandus nandus	√	√	√	√	√	√	√	√	√	√
Nemacheilus botia	√	√		√	√	√				√
Nematopalaemon tenuipes	√	√	√	√	√	√		√	√	√
Notopterus notopterus	√	√	√	√	√	√	√	√	√	√
Ompok bimaculatus		√		√	√				√	√
Ompok pabda	√	√	√		√				√	
Ompok pabo	√			√		√	√	√	√	√
Oreochromis mossambicus			√			√		√		

Oreochromis niloticus	√	√		√						
Osteobrama cotio	√	√	√	√	√	√			√	√
Oxygaster gora	√	√	√	√				√		
Pseudeutropius atherinoides	√	√	√		√					
Puntius chola			√							
Puntius conchonius		√			√	√			√	
Puntius gelius			√	√	√				√	
Puntius gonionotus	√	√						√		
Puntius phutunio			√	√						
Puntius sarana	√	√	√	√	√	√				
Puntius sophore	√	√	√	√	√	√	√	√	√	
Puntius terio	√	√	√	√		√			√	
Puntius ticto	√	√	√	√	√	√	√	√	√	√
Rasbora daniconius					√					
Salmostoma bacaila	√	√	√		√				√	
Salmostoma phulo	√	√	√		√	√	√	√	√	√
Sperata aor					√	√				
Tenualosa ilisha		√								
Tetraodon cutcutia	√	√	√	√	√	√	√	√	√	√
Tor tor	√									
Wallago attu	√	√	√	√	√	√		√	√	√
Xenentodon cancila	√	√	√	√	√	√	√	√	√	√
Total number of species	58	60	60	57	52	54	35	52	53	41

Note: '√' indicates beel-wise presence of a particular species.

The four mola stocked beels (Mangolpurer Dubi beel, Juri Panjuri beel, Piranagar beel and Rajghori beel) indicated that about 33 different species of fish benefited from the mola enhancement related activities which were not present in respective beel area at the time of baseline study in 2012-2013 year. The highest number of regenerated fish species (18) in the final was found in the Rajghori beel followed by 12 species in Piranagar beel, 9 species in Juri Panjuri beel and 6 species in Mangolpurer Dubi beel. However, some available species during baseline survey were found unavailable in the final impact year. The highest number (16) of disappeared fish species were documented in the Kochua beel followed by 12 species from the Juri Panjuri beel, 10 species from the Piranagar beel, 4 species from the Mangolpurer Dubi beel and 1 species from Rajghori beel. Hence, the Kochua beel was out of mola enhancement and total numbers of species decreased from 53 to 41 within four years.

Biodiversity index. The average value of Shannon-Wiener biodiversity index (H value) of 4 stocked wetlands was 2.92±0.49 and 2.97±0.48 in the baseline and final year, respectively. Comparing baseline year with the final impact year, it was observed that H value increased in all stocked *beels* except one (Juri Panjuri beel). In 2015-2016, the highest diversity index was found at Mongolpurer Dubi beel (H=3.62) and lowest diversity index at Rajghori beel (H=2.50). On the other hand, Kochua beel showed downward trend of H value comparing baseline value (Table 8).

Table 8

Trends in fish biodiversity at 5 study sites

Name of the beels	*Diversity (H) value*		*Remarks*
	2012-13	*2015-16*	
Mangolpurer Dubi beel	3.53	3.62	Upward
Juri Panjuri beel	3.07	2.98	Slightly downward
Piranagar beel	2.66	2.76	Upward
Rajghori beel	2.41	2.50	Upward
Average (mean±SD)	2.92 ± 0.49	2.97 ± 0.48	Upward
Kochua beel (control)	2.51	2.47	Downward

Table 9

One way ANOVA table showing comparisons of mola production, annual fish production, mola CPUA, annual CPUA, and H value between baseline and final year

Mean scores	*Source of variation*	*Sum of squares*	*df*	*Mean square*	*F*	*Sig. (P)*
Mola production	Between groups	335896.668	1	335896.668	9.806	0.020
	Within groups	205515.270	6	34252.545		
	Total	541411.938	7			
Total production	Between groups	11704500.871	1	11704500.871	6.956	0.039
	Within groups	10096067.196	6	1682677.866		
	Total	21800568.067	7			
Mola productivity	Between groups	12490.692	1	12490.692	7.837	0.031
	Within groups	9563.090	6	1593.848		
	Total	22053.781	7			
Fish productivity	Between groups	496745.314	1	496745.314	1.292	0.299
	Within groups	2307213.329	6	384535.555		
	Total	2803958.643	7			
H value	Between groups	0.005	1	0.005	0.019	0.894
	Within groups	1.410	6	0.235		
	Total	1.414	7			

Note: df = degree of freedom, F = The F statistic used with ANOVA, Sig.= Significance

Discussion. Small indigenous species of fish played a vital role in rural areas of Bangladesh through providing regular dietary protein, vitamin A, calcium, and iron (Jahan et al 2014). Mola, an important SIS, was very abundant in rivers, canals, beels, streams and ponds before 1980. Through the continuous degradation of open water along with various manmade causes SIS, especially mola production was drastically reduced. Mola enhancement in the haor areas through SCBRMP project was an experimental initiative to increase the SIS production. This study conducted to find out the impact of mola in annual fish production and fish biodiversity in the wetlands after execution of mola enhancement program. The results showed positive significance ($p<0.05$) in case of annual fish production and mola production in some selective beels of Sunamganj (Table 9).

Impact of mola enhancement program on annual fish production. Present study revealed that, the annual fish production along with mola production significantly increased ($p<0.05$) in the project beels comparing to the baseline year. In four mola stocked beels, the average CPUA during the baseline year (2012-2013) was 745.63 $kgha^{-1}year^{-1}$ which increased by almost 66.84% (1244.00 $kgha^{-1}year^{-1}$) by the 4th year (2015-2016) of the mola stocking. The increasing trends of production revealed that fish species are probably benefited from the management activities in the waterbodies implemented by the project. On the other hand, the CPUA of non-stocked Kochua beel also increased by 9.24% (from 665.05 to 726.52 $kgha^{-1}year^{-1}$). This result can be comparable with the national fish productivity in the beel area of Bangladesh. In 2012-2013 fish productivity from beels was 769.98 $kgha^{-1}year^{-1}$ which increased by almost 8.59% (836.13 $kgha^{-1}year^{-1}$) in 2015-2016 (FRSS 2017; Figure 4). The average growth rate of increasing CPUA was more than 7 times greater in stocked beels than non-stocked beel. Mola enhancement program significantly contributed to the rise of the annual fish production and might be associated with the good management practices implemented in the study areas. Increased mola production increases micronutrient enriched mola consumption rate than previous years might be helpful to reduce the malnutrition of the user group.

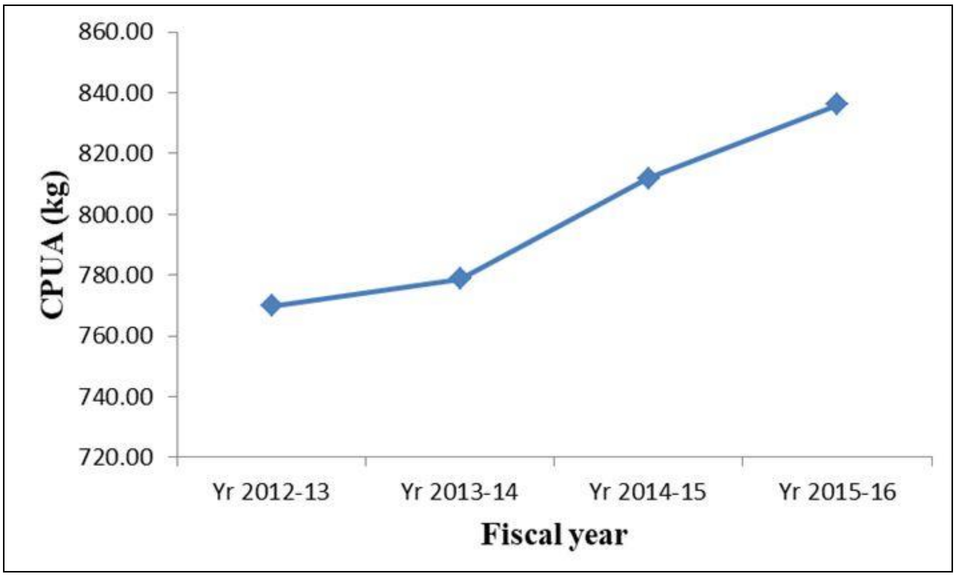

Figure 4. Fish productivity (CPUA) from the beels of Bangladesh (FRSS 2017).

Akter et al (2013) documented that after stocking of mola brood (329 kg) during 2011-2012 in different ditches of Soma Nadi jalmohal (61.25 ha) (jalmohal is a government owned public wetland or water body leased to the people) at Derai sub district in Sunamganj district during the dry season and ban on harvesting of brood fish and small fry during dry season showed rapid increase in production of both mola and other small fish species from the floodplain. Community based management system took special measures on regulation of gear use. During the baseline year (2010-2011), annual fish production and mola production was 19736 kg (322 $kgha^{-1}year^{-1}$) and 7 kg (0.11 $kgha^{-1}year^{-1}$) which increased to 47878 kg (782 $kgha^{-1}year^{-1}$) and 3827 kg (62 $kgha^{-1}year^{-1}$), respectively by the 3rd year (2012-2013) of the mola enhancement program. After mola stocking in Soma Nadi jalmohal mola ranked 3rd position in the catch. This study supported the present findings that stocking of mola brood in dry season and associated management is the factors behind higher production of mola and other fish in the stocked beels.

During baseline year (2012-2013), total annual income from four beels was about US$ 28446.41, where mola contributed only US$ 230.31. After stocking of mola brood and management practices, finally in 2015-2016 total annual income was about US$ 44553.4375, where mola contributed US$ 2892.64. Akter et al (2013) found that total annual income from selling of fishes was progressively increased from US$ 1977.80 to US$ 57706.06 comparing baseline and final year, respectively where mola contributed US$17.5 and US$ 6081.99, respectively. It is documented that after stocking of 329 kg mola brood in the ditches of Soma Nadi jalmohal generate US$ 6064.49 more income than baseline year income only from mola (Akter et al 2013). Mola culture with carps brings double benefits through nutrient intake and income generation for haor areas people. Lorenzen (2005) reported fish stock enhancement is biologically and economically very effective which is directly and indirectly contributed to the fisheries related livelihoods, natural recruitment of certain species and economic condition. In the present study, establishment of sanctuaries, mola stocking and community-based management process helped to increase the production of nutrient rich mola and other fish species in the haor wetlands and increased the rate of fish consumption and income of rural people in the haor region.

Impact of mola enhancement program on fish species diversity status. Species diversity always indicates the healthy condition of an ecosystem. It was agreed by local people of the study areas that inland fisheries diversity and production status was poor comparing to their childhood memory. According to the present study fish species identified 60, 57, 54 and 52, respectively in Mangolpurer Dubi beel, Juri Panjuri beel, Piranagar beel, Rajghori beel which were comparatively higher to baseline study of WorldFish research team at 2012-2013 where fish species were recorded 58, 60, 52 and 35, respectively. At the time of baseline study 53 fish species were found in Kachua beel (control site) and finally after 3 years only 41 fish species were observed. Akter et al (2013) documented that open water mola enhancement and beel management practices through involving local people were responsible for increasing fish diversity of Soma Nadi jalmohal. During the baseline year (2010-2011), total number of fish species was 49 which increased to 58 and 68 species by the 1st year (2011-2012) and 2nd year (2012-2013) of the mola enhancement program, respectively. This study supported the results of the present study.

Comparing baseline year (2012-2013) with final survey year (2015-2016), it was observed that species diversity index (H value) increased in all mola stocked beels except one beel (Juri Panjuri beel). The possible reason behind decreasing fish diversity in the Juri Panjuri beel was poor management by the BUG members due to bigger size of the water body where some illegal fishing occurred which was beyond the control of the BUG members. However, the increasing H value suggested that maximum fish species probably benefited from the management activities in the water bodies, as during critical or sensitive stages of their life cycle (dry months), they are safeguarded by BUG members. It is indicated that stocking of mola brood with associated management is one of the most important factors behind higher diversity.

Conclusions. The present study was carried out to know the impact of stocking mola (*Amblypharyngodon mola*) on the annual fish production and fish species diversity in the wetland. During the study period, a positive impact of mola enhancement program was documented in Mangolpurer Dubi beel, Juri Panjuri beel, Piranagar beel, and Rajghori beel of Sunamganj through increased production of mola and other SIS with increased fish biodiversity. Good management practices such as- establishment of sanctuary, fishing ban for few months, stopping indiscriminate killing of fish, keeping the ecosystem undisturbed etc., also played a key role to enhance production and biodiversity. The awareness training program of the fishermen was useful to engage them in the good management practices. Finally, the findings of this study show that this type of intervention has the potential to be replicated in other wetlands of Bangladesh to boost fish production, biodiversity, household income, and food security.

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Conflict of interest. The authors declare that there is no conflict of interest.

References

Ahamed F., Ahmed Z. F., Hossain M. Y., Ohtomi J., 2017 Growth and longevity of the mola carplet *Amblypharyngodon mola* (Cyprinidae) in the Payra River, southern Bangladesh. Egyptian Journal of Aquatic Research, 43:291–295.

Akter S., Barman B. K., Thilsted S. H., 2013 Production of micronutrient-rich small fish in the floodplains. In: National fish week compendium 2013 (Bengali), Department of Fisheries, Ministry of Fisheries and Livestock, Bangladesh, pp. 43-46.

Alam M. F., 2002 Socioeconomic aspects of carp production and consumption in Bangladesh. In: Penman, D.J., Hussain, M.G., McAndrew, B.J., Mazid, M.A. (Eds.) Proceedings of a workshop on genetic management and improvement strategies for exotic carps in Asia, Dhaka, Bangladesh. Bangladesh Fisheries Research Institute, Mymensingh, Bangladesh, pp. 83-93.

Alam M. F., Das T. K., Kazal M. M. H., 2007 Community based fisheries management (CBFM) in Sunamganj District of Bangladesh: The nature of cooperation and conflicts. Bangladesh Journal of Fisheries Research 11(1):93-104.

Alam M. J., Dewan S., Rahaman M. R., Kunda M., Khaleque M. A., Kader M. A., 2004 Study on the cultural suitability of *Amblypharyngodon mola* with *Barbodes gonionotus* and *Cyprinus carpio* in a farmer's rice fields. Pakistan Journal of Biological Sciences 7:1242-1248.

Arefin S., Kunda M., Islam M. J., Pandit D., Haque A. T. U., 2018 Status of fish and shellfish diversity and their decline factors in the Rupsa River of Khulna in Bangladesh. Archives of Agriculture and Environmental Science 3(3):232-239.

Bogard J. R., Thilsted, S. H., Marks G. C., Wahab M. A., Hossain M. A., Jakobsen J., Stangoulis J., 2015 Nutrient composition of important fish species in Bangladesh and potential contribution to recommended nutrient intakes. Journal of Food Composition and Analysis 42:120-133.

Daniels R. J. R., 2002 Freshwater fishes of Peninsula India. Universities Press, Hyderabad.

Das S. R., Pandit D., Harun-Al-Rashid A., Tasnim N., Kunda M., 2022 Impacts of brush pile fishing on fish biodiversity: A case study of the Shari-Goyain River in Bangladesh. Heliyon 8(7):e09903.

Department of Fisheries (DoF), 2018 Yearbook of fisheries statistics of Bangladesh 2017-18. Fisheries Resources Survey System (FRSS), Department of Fisheries, Bangladesh 35:129.

Fisheries Resources Survey System (FRSS), 2017 Yearbook of fisheries statistics of Bangladesh 2015-16. Fisheries Resources Survey System (FRSS), Department of Fisheries, Bangladesh 33:124.

Hossain M. A., Afsana K., Shah A. K. M., 1999 Nutritional value of some small indigenous fish species (SIS) of Bangladesh. Bangladesh Journal of Fisheries Research 3(1):77-85.

Hussain M. G., Salam M., 2007 Basic service delivery advocacy: review report, development wheel (Dew), Dhaka.

Islam M. R., Kunda M., Pandit D., Rashid A. H. A., 2019 Assessment of the ichthyofaunal diversity in the Juri River of Sylhet district, Bangladesh. Archives of Agriculture and Environmental Science 4(4):488-496.

International Union for Conservation of Nature (IUCN) Bangladesh, 2015 Red list of Bangladesh, Volume 5: Freshwater fishes. IUCN, International Union for Conservation of Nature, Bangladesh Country Office, Dhaka, Bangladesh, xvi+360 p.

Jahan R., Quaiyum M. A., Sarker B. S., Hossain M. B., Jaman K. M., Rahman S., 2014 Biodiversity and seasonal abundance of small indigenous fish species (SIS) in the rivers and adjacent beels of karimganj (Kishoreganj, Bangladesh). Asian Journal of Animal Sciences 8(2):38-46.

Jayaram K. C., 1999 The freshwater fishes of the Indian Region. Narendra Publishing House, Delhi.

Kibria M. G., Ahmed K. K. U., 2005 Diversity of selective and non-selective fishing gear and their impact on inland fisheries in Bangladesh. Naga, World Fish Center Quarterly 28(1-2):43-48.
Lorenzen K., 2005 Population dynamics and potential of fisheries stock enhancement: practical theory for assessment and policy analysis. Philosophical Transactions of the Royal Society B: Biological Sciences 360:171-189.
Mohsin S. M., Khan A. K. M. F., 2014 Adoption of mola in community managed waterbodies, enhanced CPUA and bio-diversity in Sunamganj haor basin: An example of successful technology transfer in SCBRMP. In Thilsted, S.H., and Wahab, M.A. (Eds.). (2014). Production and conservation of nutrient-rich small -sh (SIS) in ponds and wetlands for nutrition security and livelihoods in South Asia. Proceedings of a World Bank/SAFANSI Funded Regional Workshop on Small Fish and Nutrition. Dhaka, Bangladesh. 1st - 2nd March 2014, 47 p.
Pandit D., Kunda M., Islam M. J., Islam M. A., Barman P. P., 2015a Assessment of present status of fish diversity in Soma Nadi Jalmohal of Sunamganj in Bangladesh. Journal of the Sylhet Agricultural University 2(1):127-135.
Pandit D., Kunda M., Rashid A. H. A., Sufian M. A., Mazumder S. K., 2015b Present status of fish biodiversity in Dekhar Haor, Bangladesh: a case study. World Journal of Fish and Marine Sciences 7(4):278-287.
Rahman A. K. M., 2005 Freshwater fishes of Bangladesh, second edition. Zoological Society of Bangladesh, University of Dhaka, Dhaka, Bangladesh, 263 p.
Saha B. K., Islam M. R., Saha A., Hossain M. A., 2009 Reproductive biology of the mola carplet *Amblypharyngodon mola* (Hamilton) (Cypriniformes: Cyprinidae) from Netrakona Water. Bangladesh Journal of Scientific and Industrial Research 44:377–379.
Shannon C. E., Weaver W., 1949 The mathematical theory of communication. Urbana, IL: University of Illinois Press, 54 p.
Talwar P. K., Jhingran A. G., 1991 Inland fishes of India and adjacent countries. Oxford and IBH Publishing, Calcutta.
Thilsted S. H., Roos N., 1999 Policy issues on fisheries in relation to food and nutrition security. In: Ahmed M, Delgardo C, Sverdrup-Jensen S, Santos RAV (Eds.) Fisheries policy in developing countries: issues, priorities and needs. International Center for Living Aquatic Resources Management (ICLARM) Conference Proceedings 60, Manila, Philippines, pp. 61–69.
Wahab M. A., 2003 Small indigenous fish species of Bangladesh: potentials for culture and conservation. In: Wahab, M.A., Thilsted, S.H., Hoq, M.E. (Eds.) Small indigenous species of fish in Bangladesh, pp. 1-12.

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