BIODIVERSITY AND CONSERVATION OF FISHERIES RESOURCE OF HALDA RIVER

Azadi, M. A. and M. Arshad-ul-Alam[1]

Department of Zoology, University of Chittagong, Chittagong-4331, Bangladesh; [1]*Bandarban Government College, Bandarban Hill District, Bangladesh*

Abstract

The present study was carried out to document the fin and shell fish diversity of the Halda River, Chittagong during the period (January 2007 to December 2008). A total of 1017 catch samples of fin and shell fish was collected from 34 different types of gear and analyzed. Proportion of average daily catch (in number) was used to obtain the diversity indices. Simpson index of diversity (D) (0.54-0.66), Shannon index (H) of diversity (0.25-0.32) (re-scaled) and Evenness (E) (0.27-0.35) were calculated for fin fishes and shell fishes for the entire fishing area (39 km) of the river. Species richness (S) was observed 92 (83 fin fish and nine prawn species, including three exotic species) belonging to 14 orders, 37 families, and 72 genera. Maximum number of species was recorded under the family Cyprinidae (19 species), followed by the family Gobiidae (11 species). Fin fish species richness (FSR) was recorded as 83, which is higher than the earlier records (65) from the river. The actual total fin fish and shell fish species richness was 120 species (106 fin fish and 14 prawn species). Species richness was higher in downstream (71 and 83 species) than of mid (67 and 72 species) and upstream areas (61 and 69 species) of the river for the years 2007 and 2008, respectively. ANOVA analysis showed no significant difference between the populations of two years and among the populations of the three sections of the river. Three critically endangered, nine endangered and eight vulnerable fish species were observed in the river. Strong dominance was observed for *Corica soborna* (55.1%), followed by *Macrobrachium rosenbergii* (19.2%), *Setipinna phasa* (11.8%), *Glossogobius giuris* (6.9%) and *Macrobrachium villosimanus* (2.0%). Three exotic fish species comprised less than 0.001% of the catch. Fish diversity and carp spawning were found under threat due to over fishing, cutting of five main oxbow-bend, blocking of normal water flow of 12 tributaries and upstream water flow interruption by two rubber dams, embankment and pollution, poor or no rainfall around lunar phases, high temperatures during breeding period (April to June), sedimentation and erosion.

***Key words*:** Biodiversity, conservation, fin fish, shellfish, major carps spawn fishery, Halda River.

INTRODUCTION

Tidal River Halda (22°54´ North and 91°48´ East to 22°24´ North and 91°53´ East) originates in the hill streams of Khagrachari District and flows through the Fatickchari, Hathazari and Rouzan upazila covering a length of 88 km and meets the River Karnaphuli, which after traversing 20 km empties into the Bay of Bengal. The River Halda is considered as an important natural spawning ground of four species of Indian major carp (*Catla catla*, *Labeo rohita*, *Cirrhinus mrigala* and *Labeo calbasu*). This is the river where major carps naturally spawn and is only the tidal river from which naturally-produced fertilized eggs of major carps are collected. They are hatched in the mud-made scoop on the river bank and has long been the source of naturally-produced carp fry for country's pond fish culture (Azadi 1979, 1983, 2004; Patra and Azadi 1985a, 1985b). The river is also one of the major sources of brood and post-larvae (PL) of the giant freshwater shrimp, *Macrobrachium rosenbergii*. A rich assemblage of marine, estuarine, riverine, floodplain and migratory fin fish and shell fish inhabit the Halda River. Besides fisheries, there are multiple uses of this river, i.e. irrigation,

navigation, sand collection and drinking water (presently daily two crore litre) supply to the Chittagong city dwellers. The river is fed by several hilly streams starting from its origin, including 12 important tributaries located in the lower region (downstream) of the river, where four spawning grounds of major carps are situated (Azadi 2004).

During 1975-76 and 1982-1983, 12 major tributaries of the lower Halda were blocked by 13 sluice gates interrupting the normal water flow and local migration of fish and other aquatic lives and 47 km embankment was made by the Bangladesh Water Development Board for irrigation and flood control. From 1928 to 2002 five major oxbow bends (spawning ground of major carps) of the river were lost, in the process of making the river straight by loop cutting by the local people to protect their homesteads from severe erosion (pres. comm. with local people). Recently construction of two rubber dams at the upstream blocked the main river water flow during summer. The impact of this habitat alteration and climate change (late rainfall or no rainfall around the lunar phase) caused severe declination in the major carp fry production from 2470 kg in 1945 to 20 kg (20 June) in 2004 (Khan and Azadi 2006) and 60-70 kg in 2015 (by two times spawning).

Knowledge on the status of biodiversity of any water bodies or terrestrial areas are essential for formulating proper management policy, but no detailed works were made on the biodiversity of the Halda River. Studies on the fishes of Halda and Ichthyofauna of Halda were made by Rainboth (1978), Azadi and Arshad-ul-Alam (2013), respectively. Other researches on inland waters of Bangladesh (Azhar *et al.* 2007, Sarker *et al.* 2008, Zafar *et al.* 2007, Azadi and Arshad-ul-Alam 2014) could be cited as examples in the line.

Researches on limnology, fishery, plankton ecology, management of spawning and spawn fishery, restoration of spawning habitats of major carps, Halda Fishery and fishing intensity were done by different authors could be cited as the related work of the present study (Azadi 1979, 1983, 1985 and 2004; Khan and Azadi 2006, Patra and Azadi 1984, 1985a, 1985b and 1987; Tsai *et al.* 1981, Arshad-ul-Alam 2011 and 2013). During 2007, Bangladesh government has undertaken a project on the restoration of the natural breeding habitats of the Halda River emphasizing on the spawn fishery of the river. This investigation was carried out to know the fin fish and shell fish biodiversity and spawning status of major carps of the Halda River. The work suggested for the conservation and habitat restoration of the river.

MATERIAL AND METHODS

Biodiversity and abundance of fin fish and shell fish of the River Halda were conducted fortnightly by catch sampling and direct observation during January 2007 to December 2008. The entire fishing area of the River was divided into three sections, i.e. upstream (S_1), midstream (S_2), and downstream (S_3) (Table 1, Fig.1). Differences and variation in the abundance and distribution of species among the different sections were examined. Spawning and spawn fishery data had been collected since 1977 by direct field visit during spawning period, from the Department of Fisheries and from the articles of Ahmed (1948, 1955).

During two-year period of study, a total of 1017 fin and shell fish catch-samples were collected from 34 types of gear. All professional, subsistence, recreational, occasional and illegal fishing gears used at day and night in the study area were monitored. Catch composition in respect to species and numbers were recorded. Sum of the average daily catch (in number of fish) by all gears were used for obtaining the proportion of different fish

species. Abundance was estimated by using the "proportion of species" formula given below (Table 2).

The total daily catch (Y_d) was obtained using the formula 1 of de Graff and Chinh (1992);

$$Y_d = \sum_g \overline{CPUE_g} \times \overline{f_g} \quad \text{---------- (1)}$$

Where, Y_d= total daily catch, $CPUE_g$ = daily mean catch per unit effort for gear and f_g= mean effort (gears/day). Diversity was measured by the number of species (species richness-S) and by using the three indices, viz. Simpson (D) (Simpson 1949), Shannon (H) and species evenness (E) (Shannon and Weaver 1949,Wolda 1983) with the help of formulas 2 - 5:

Species richness (S) = Number of species in a given area------- (2)

Simpson index (D) = $\sum(Pi)^2$ ---------- (3)

Where Pi = the proportion (n/N) of i^{th}species in the sample, n = total number of individual(s) of a particular species and N = total number of individual(s) of all species.

Shannon index (H) = $-\sum$ (Pi lnPi) ---------- (4)

Evenness (E) = H/ ln S ---------- (5)

Simpson index (D) (3) and Shannon index (H) (4) were rescaled from 0 to 1 (Odum 1980). ANOVA analysis (three-way) was done to determine the variation in the population (%) of top ten species among the data of the three sections. The *t*-test was done to find out the variation in Shannon index (H) (rescaled) among the three sections and between two years.

Table 1. Length and location of the different sections of study area (Section1, Section 2 and Section 3).

	Section 1 (S_1)	**Section 2 (S_2)**	**Section 3 (S_3)**	**Total study area**
Location	Upstream	Midstream	Downstream	Halda River
Length (km)	20	10	9	39
Area (m^2)	135	94.5	121.5	351
Average width (m)	67.5	94.5	135	
Distance from Sea (km)	45	35	26	65 (up to upstream)

Table 2. Population size and corresponding marks used to measure abundance.

Size of population for an individual species	**Mark**	**Abundance**
More than 50 % of the population (½)	A++	Very common
More than 1 per 10 (1/10)	A+	Common
More than 1 per hundred (1/100)	A	Less common

RESULTS AND DISCUSSION

Composition and abundance of Fin and Shell fish species

A total of 74 fin fishes and eight prawn species was observed in the 39 km study area during the year 2007, whereas 80 fin fishes and nine prawns were observed during the year 2008. During the two-years of the study, a total of 92 species was recorded. Among which 83 fin fish and nine prawn species, belong to 14 orders, 37 families, and 71 genera. Three exotic fin fish species were also recorded over the total studied area (Table 3). Maximum number of species was recorded under the family Cyprinidae (19 species) followed by the family Gobiidae (11 species). Similar results were obtained in the River Sangu, where maximum

number of species were under the family Cyprinidae (26 species) followed by the family Gobiidae (11 species) (Azadi and Arshad-ul-Alam 2014).

The proportion of different species in the population was uneven with a great difference (55%). *Corica soborna* was the most dominant species in all the three locations. It constituted about 55 % of the total population. The population of the top ten (rank) species showed also remarkable differences (Table 3). Analysis showed highly-significant differences among the populations of the top ten species ($F=50.63$, df=9 and 47, $p<0.01$). *Corica soborna* (55.1%) (rank-1), *Macrobrachium rosenbergii* (19.2%) (rank-2), *Setipinna phasa* (11.8%) (rank-3), *Glossogobius giuris* (6.9%) (rank-4) and *Macrobrachium villosimanous* (2.0 %) (rank-5) were the most dominant species. Combined data for the study period showed that the remaining 82 species, other than top ten, comprised only 1.7% of the total population. Three exotic species *Aristichthys nobilis*, *Hypophthalmichthys molitrix* and *Oreochromis niloticus* comprised only 0.001% of the total population size.

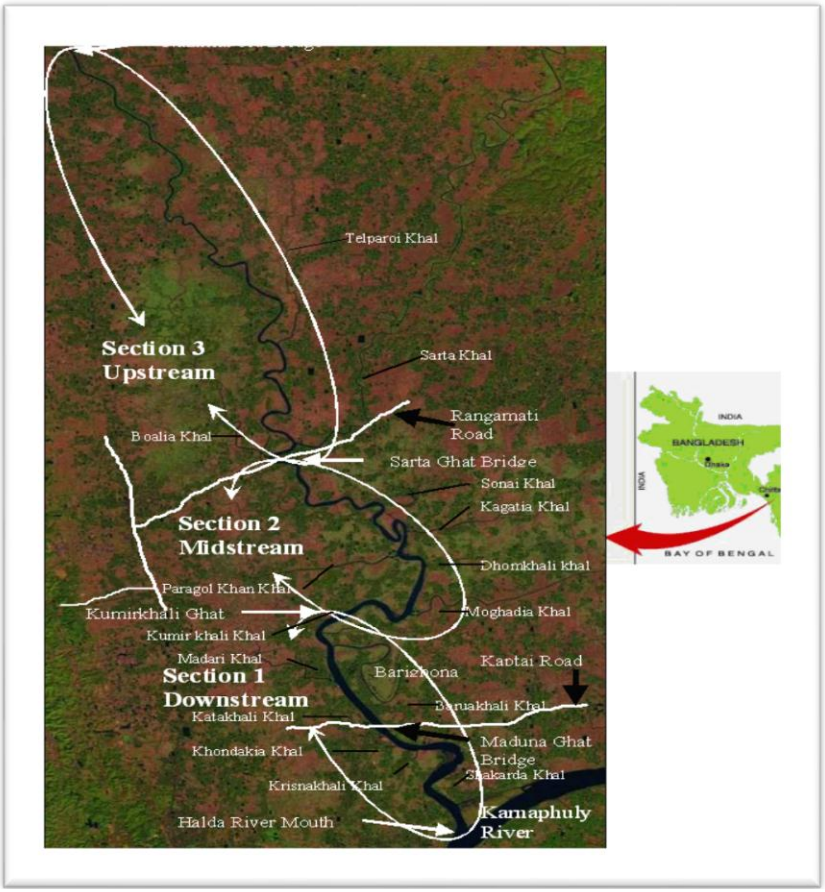

Fig. 1. Entire fishing zones of the River Halda showing the three sampling sections (1, 2 and 3).

These exotic species were found occasionally from May to October, when beels and ponds adjacent to the Halda were flooded. Occasional presence of the exotic species was very poor and was not threatening for the native species. In some Indian water bodies, indigenous fishes were reduced and replaced by the introduced exotic fish (Johal and Tendon 1993, Kar *et al.* 2006). *Anguilla bengalensis* and *Moringua macrocephalus* were very rare in the population.

Among migratory species, *T. ilisha* and *J. coitor* were found throughout the year, whereas coastal *S. panijus*, *P. paradiseus* and *P. serperaster* were not very common and marine *S. argus* was rare. Juveniles of anadromous migratory *M. cuja* were caught by small mesh set-bag net and lift net along with other immature fishes. No adult *M. cuja* was found. Estuarine species *S. phasa* is one of the most commercially-important species. The species occupied 11.8% of the total catch and was found throughout the year in the downstream. The pelagic fish species *X. cancila* and *H. limbatus* are resident fish of Kaptai Lake (Ahmed and Hasan 1981, Hafizuddin *et al.* 1989) and were found in the Halda River after torrential rain and flood. It happens when the spillway of Kaptai dam at upstream of the Karnaphuli River is opened to reduce high-water pressure.

Due to the tidal (estuarine) nature of the River Halda, an assemblage of riverine, floodplain and marine organisms was noticed. Difference in abundance was significant among the population of different species causes low fin-fish evenness. Some fin fish species (*C. soborna, S. phasa, G. giuris)* were highly abundant. Most of the species were present with very low abundances. Some species, such as *A. bengalensis*, *L. gonius*, *C.* magur, P. *pangasius*, *M. pancalus*, were represented by only a few individuals. Some marine fishes entered the estuary occasionally, which varied seasonally depending on tidal flow and lunar periodicity. Marine fish *O. nigromarginatus* was an occasional invader in the river. The fishes of floodplain origin were found in low abundance. The actual number of fin fish species richness (FSR), including previous records (Rainboth 1978) states that it totals 106 species, which is much higher when compared to some larger river systems of Asia, including Irrawady (79 species), Narmada (77 species), Sepik (55 species) and Chalakudy (98 species) (de Silva *et al.* 2007, Raghavan *et al.* 2008).

Table 3. Composition and abundance of different fishery species in the River Halda during 2007 and 2008. (A++=Very common, A+ = Common, A = Less common, B+= Moderate, B = Few, C+ = Very few, C= Rare, D+ = Very rare, D = Very very rare).

Order	Family	Species name	2007	2008	%	Rank
Anguilliformes	Anguillidae	*Anguilla bengalensis*		D	0.000005	91
	Moringuidae	*Moringua raitaborua*	C+	C+	0.0027	47
		Moringua macrocephalus		D	0.000004	92
	Ophichthidae	*Pisodonophis boro*	B	C+	0.008	32
Clupeiformes	Clupeidae	*Corica soborna*	A++	A++	55.14	1
		Gudusia chapra	B+	B+	0.35	11
		Tenualosa ilisha	B	B	0.047	22
	Engraulidae	*Setipinna phasa*	A	A+	11.83	3
Osteoglossiformes	Notopteridae	*Notopterus notopterus*		C	0.00006	86
Cypriniformes	Cyprinidae	*Labeo ariza*	D+	C	0.00008	85
		Labeo calbasu	C	C+	0.00101	62
		Labeo gonius	C	D	0.00014	79
		Labeo rohita	C+	C+	0.00178	55
		Catla catla	C+	C+	0.00173	56
		Cirrhinus mrigala	C+	C+	0.008	33
		Aristichthys nobilis	C	C	0.00061	67
		Hypophthalmichthys molitrix	D+	D+	0.00004	87

		Amblypharyngodon mola	C+	C+	0.0059	37
		Chela laubuca	C+	C	0.00121	59
		Crossocheilus latius	C+	C+	0.0025	48
		Osteobrama cotio	C	C	0.00058	68
		Puntius sophore	B	B	0.016	30
		Pethia ticto	B	C+	0.035	24
		Pethia gelius	B	B	0.021	28
		Pethia conchonius	C+	C	0.00084	63
		Rasbora rasbora	C	C	0.00031	71
		Salmostoma bacaila	B	B+	0.1	14
		Salmostoma phulo	B	B	0.083	17
	Cobitidae	*Lepidocephalichthys guntea*	C	C	0.00013	81
Siluriformes	Bagridae	*Sperata aor*	B	B	0.031	26
		Mystus cavasius	C+	C+	0.0059	38
		Mystus gulio	C	D+	0.0001	83
		Mystus vittatus	D+	D+	0.000037	89
	Clariidae	*Clarias magur*	D	D+	0.00004	88
	Heteropneustidae	*Heteropneustes fossilis*		C	0.00026	74
	Pangasiidae	*Pangasius pangasius*	D+	C	0.00023	76
	Schilbeidae	*Ailia coila*	B	B	0.055	18
		Clupiso magarua	C+	C+	0.0035	43
		Eutropiichthys murius	C+	C+	0.0022	50
		Eutropiichthys vacha	C+	C+	0.0061	36
		Neotropius atherinoides	C	C	0.00049	69
	Siluridae	*Ompok pabda*	C+	C+	0.002	51
		Wallago attu	C	C	0.00068	65
Beloniformes	Adrianichthyidae	*Oryzias dancena*	B	B+	0.17	12
	Hemiramphidae	*Hyporhamphus limbatus*	B	B+	0.1	15
	Belonidae	*Xenentodon cancila*	C+	C	0.0024	49
Cyprinodontiformes	Aplocheilidae	*Aplocheilus panchax*	D+	C+	0.00159	57
Syngnathiformes	Syngnathidae	*Microphis cuncalus*	B		0.008	34
Perciformes	Ambassidae	*Chanda nama*	C+	C+	0.00103	61
		Parambassis ranga	C	C+	0.0031	45
		Pseudambassis baculis		C	0.00009	84
	Scatophagidae	*Scatophagus argus*		C	0.00014	80
	Sciaenidae	*Johnius coitor*	B	B	0.048	21
		Macrospinosa cuja	B	C+	0.0058	39
	Cichlidae	*Oreochromis niloticus*	C	C	0.00017	78
	Anabantidae	*Anabas testudineus*	D+	C	0.00026	75
	Sillaginidae	*Sillaginopsis panijus*	B	C+	0.0077	35
	Gobiidae	*Glossogobius giuris*	A+	B+	6.85	4
		Brachygobius nunus	B	B+	0.1	16
		Apocryptes bato	B+	B+	0.68	8
		Pseudapocryptes elongatus	C	C	0.00027	73
		Parapocryptes serperaster		C+	0.00071	64
		Oxyurichthys microlepis	D+	C+	0.0046	41
		Taenioides cirratus	B+	B+	0.56	10
		Odontamblyopus rubicundus	C+	C+	0.00187	53
		Ophieleotri saporos	C+	C+	0.0039	42
		Stigmatogobius sadanundio	C+	C	0.00199	52
		Periophthalmodon schlosseri	C		0.00011	82
	Osphronemidae	*Colisa fasciata*		C	0.00042	70

		Trichogaster chuna	C+	C+	0.0032	44
	Polynemidae	*Polynemus paradiseus*	C	C	0.00064	66
	Channidae	*Channa orientalis*	C+		0.00139	58
		Channa punctatus	C+	C	0.00181	54
		Channa striatus	C	C	0.0003	72
	Opistognathidae	*Opisthognathus nigromarginatus*		D+	0.000032	90
Mugiliformes	Mugilidae	*Sicamugil cascasia*	B	B	0.035	25
		Rhinomugil corsula	B	C	0.0057	40
Scorpaeniformes	Platycephalidae	*Platycephalus indicus*	B	C	0.019	29
Synbranchiformes	Mastacembelidae	*Mastacembelus armatus*	C+	C+	0.003	46
		Macrognathus pancalus	D	C+	0.00115	60
		Macrognathus aculeatus	C	D+	0.00023	77
Pleuronectiformes	Soleidae	*Brachirus orientalis*	B	B	0.023	27
	Cynoglossidae	*Cynoglossus cynoglossus*	B	C+	0.013	31
Decapoda	Palaemonidae	*Macrobrachium villosimanus*	B+	A	1.99	5
		Macrobrachium rosenbergii	A+	A+	19.17	2
		Macrobrachium malcolmsonii	B+	B+	0.57	9
		Macrobrachium dolicodactylus	B+	A	0.8	6
		Macrobrachium dayanus	B	B+	0.12	13
		Macrobrachium rude	C+	B	0.055	19
		Macrobrachium birmanicus	B+	C+	0.054	20
		Macrobrachium mirabilis	C+	A	0.76	7
	Penaeidae	*Metapenaeus monoceros*		B	0.042	23
		Total	82	89	100	

Habitat preference of the recorded fish species

Table 4 shows the population structure on the basis of habitat preference. Riverine fish showed the highest population, followed by freshwater riverine prawn, estuarine fin fish and wide freshwater fin fish. There were only three truly riverine fish in the river Halda, contributing 55.2% of total population and, except for *C. soborna*, the other two species contributed only 0.1%. Estuarine fishes accounted for the third highest population (13.4%), among which *S. phasa* occupied the major part (11.8%). The percentages of population in respect to order and family are shown in Table 3.The highest percentage of population was found for the order Clupeiformes (67.4%), followed by Decapoda (23.6%) and Perciformes (8.3%); 11 other orders contributed only 0.8% of the total population.

Table 4. Number of species (S) and percentage of population structure by habitat preference in different sections (S_1, S_2, S_3) of the River Halda during the years 2007 and 2008.

Habitat preference		**S_1 2007**	**S_2 2007**	**S_3 2007**	**S_1 2008**	**S_2 2008**	**S_3 2008**	**Combined**
Riverine fin fish	S	3	3	3	3	3	3	3
	%	50.4	62.0	53.2	53.0	43.5	64.7	55.2
Estuarine fin fish	S	20	20	22	16	20	22	26
	%	2.4	7.2	13.8	18.1	7.1	19.7	13.4
Wide freshwater fin fish	S	31	35	36	40	38	43	48
	%	25.6	2.6	15.8	1.2	2.2	1.8	7.8
Fresh water (exotic) fin	S		1	2	1	2	3	3
fish	%		0.001	0.001	0.001	0.001	0.001	0.0008
Catadromous migratory finfish	S						1	1

	%						0.00002	0.000005
Marine finfish	S						2	2
	%						0.0001	0.00004
Freshwater riverine	S	7	8	8	8	8	8	8
prawn	%	21.5	28.2	17.2	27.6	47.11	13.6	23.5
	S				1	1	1	1
Marine and estuarine prawn	%				0.02	0.02	0.14	0.04
Total	S	61	67	71	69	72	83	92
	%	100	100	100	100	100	100	100

Population density

During the study period (2007 and 2008), the highest density was estimated for the small clupeid, *C. soborna*, which varied in different proportion in the three sections of the River. Rainboth (1978) reported highest dominance of *C. soborna* in the River Halda. Dominance of this small clupeid was also reported from the River Pagla (Zafar *et al.* 2007) and Kaptai Reservoir (Azadi *et al.* 1992). The second-highest population density was noticed for the freshwater giant shrimp, *M. rosenbergii*, proportionately varied in the three different sections. Hossain *et al.* (2007) recorded 38.9% shrimp population in the River Naff, where molluscs and echinoderms were included in the total population. They studied the catch from only one gear type (set-bag net), but in the present study the catch was of 34 gears. Species richness increased with the decrease of distance from the river mouth. This showed close similarities with the findings of Raghavan *et al.* (2008) in the River Chalakudy in India.

Diversity indices

Species richness (S) was higher in the year 2008 than 2007 (Table 5). Species numbers were more in downstream (71 and 83 species) than midstream (67 and 72 species) and upstream (61 and 69 species) areas during the years 2007 and 2008 respectively. Evenness (E) was low in three sections with a highest value in midstream during 2008.

Table 5. Diversity indices of Species richness (S), Simpson index (D), and Shannon index (H) (rescaled) of finfish and shellfish in the three sections (upstream-S_1, midstrem-S_2 and downstream-S_3) of the River Halda.

	2007				**2008**				**Halda**
	S_1	**S_2**	**S_3**	**Total area**	**S_1**	**S_2**	**S_3**	**Total area**	**Combined**
S	61	67	71	82	69	72	83	89	92
D	0.65	0.55	0.65	0.643	0.64	0.66	0.54	0.626	0.640
H	0.30	0.25	0.29	0.30	0.29	0.32	0.27	0.30	0.31
E	0.33	0.27	0.32	0.310	0.32	0.35	0.28	0.311	0.319

insignificant (t=0.632, df=2, p>0.05), ANOVA showed no significant difference between the populations of two years (F=0.0025, df=1 and 47, p>0.05) and among the populations of three sections (F=0.0008, df=2 and 47, p>0.05).

Values of diversity indices, such as Simpson index of diversity (D) and Shannon diversity index (H) were moderate; and highest values were observed in midstream during 2008. In the two-year study, although the total species number was higher in 2008, species diversity decreased with the decrease of evenness.

Impact of sanctuary

The declaration of sanctuary of 20-km area from Sarta Ghat Bridge to Maduna Ghat Bridge in 2007 at downstream (lower Halda) of the river showed positive impact on the number of fish species as observed in 2008. It shows similarity to the records of different researchers in the newly-established sanctuaries in the different water bodies of Bangladesh (Azhar *et al.* 2007, FAP 2005, Kader *et al.* 1999, Worldfish Center 2005). The recent (2010) extension of earlier declared sanctuary area, however, from Sarta Ghat Bridge to Maduna Ghat Bridge (20 km) to whole fishing area from Nazirhat Old Bridge to Kalurghat Bridge (40 km) seemed unscientific. It happens to be detrimental to the livelihood of the local fisher community in future. According to the of earlier Gazette notification (2 July, 2007), there was a five months (February to July) closed season for fishing which was sufficient to allow the brood fish to migrate to the spawning ground. This ground is situated between the Sarta Ghat Bridge and Maduna Ghat Bridge. After declaration of 20 km fish sanctuary, Directorate of Fisheries is facing a great problem to rehabilitate more than 2000 fishermen dependent on fishing within the 20 km sanctuary area. It stands challenging to prevent the fishing communities from fishing within the entire sanctuary area. Five-months closed season for fishing, and the banning of the detrimental gill and enclosure nets used for major carp fishing and juvenile fishing, are sufficient to protect sustainable stocks of the major carp and other fishes.

Threatened species

Of the 83 fin-fish species, 20 species were found to be threatened immediately in various categories, three of them belonged to the critically endangered, nine endangered and eight vulnerable categories (IUCN 2000). The three critically endangered species are *P. pangasius*, *C. garua*, and *E. vacha*. The nine endangered species were *L. calbasu*, *L. gonius*, *C. laubuca*, *C. latius*, *O. Cotio*, *R. rasbora*, *O. pabda*, *S. argus*, and *M. armatus*. The eight vulnerable species were *A. bengalensis*, *N. notopterus*, *P. ticto*, *S. aor*, *M. cavasius*, *C. nama*, *P. ranga*, and *C. orientalis*. In the present investigation, however, *S. aor* and *P. ticto* were observed few, *M. armatus*, *C. garua* and *E. vacha* were very few; other threatened species were rare or very rare. In the study six fin fish species (*M. macrocephalus*, *L. ariza*, *O. dancena*, *P. elongates*, *O. aporos*, and *O. nigromarginatus*), which were moderate to very rare. These are newly reported from the Halda River, which were not assessed earlier (IUCN 2000).

Halda is a unique bioresource

The River Halda is a unique bioresource of the country. Besides rich in diversity of fin fish and shell fish species, carp spawn fishery of the Halda River has also been contributing tremendously in the country's aquaculture and fish hatchery. The river is supplying natural pure gene pool of carp seed (carps pure gene bank) since time immemorial. Out of four stocks of major carps of Indian subcontinent, three stocks (Ganga-Padma stock, Brahmaputra-Jamuna Stock, and Barak-Meghna stock) breed in the three trans-boundary rivers in Indian region (Ganga, Brahmaputra and Barak). Only the Chittagong stock (Halda-Karnaphuli-Sangu stock) major carps breed and spawn in the Halda River within Bangladesh region. To evaluate the economic importance of the Halda River bioresource, an estimation

of the price of carp fry is given here. In 1945, a total of 2470 kg carp fries was produced in the Halda river, which later declined tremendously (60-70 kg in 2015) (Fig. 2).

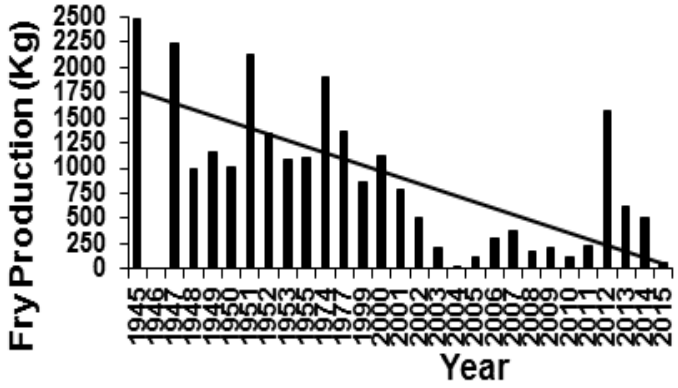

Fig. 2. Historical major carps fry production trend in Halda River (1945-2015).

If the earlier production rate continued then from 2470 kg fries (per year), after rearing three steps in pond within a year (price of fries-Tk. 111.15 million, considering 40% mortality price of fingerling-Tk. 889.2 million and considering 40% mortality price of stocked large fish-Tk. 40,014.00 million, value added) a total of Tk. 41,014.35 million (equal to US$ 525.825 million, 1 US$ =Tk. 78) could be earned. This is almost near to present financing share (US$ 600 million) of GoB for the Padma Multipurpose Bridge project. For enhancing the country's future economy the bioresource of the aquatic bodies like Halda River should be given prime importance for conservation.

Causes of declining carps spawning and fish biodiversity

Climate change, i.e. late rainfall, less or no rainfall around lunar phases and high temperature during major carp breeding time (April to June) are major natural causes for decline of biodiversity in the river as a whole. There are several man-made causes, such as five main loop cutting in the spawning area of major carp (destruction of five oxbow bends) to make the river straight to protect the homesteads from erosion, establishment of 13 sluice gates on 12 big tributaries in the lower Halda during 1976-1983 for irrigation and flood control have blocked the normal water flow and local fish movement from the tributaries to the river and vice versa. 47 km embankment for flood control closed the heart bit (tidal flow and catchment areas water flow) of the river. Two rubber dams constructed during the years 2011 and 2013 at upstream of Halda in Fatickchari upazila have also blocked the normal water flow from upstream during summer. This flow is essential for carp breeding. Indiscriminate catch of fish by 34 types of gears (during 2002-2008), instead of 10 used during 1978 (Chong 1979, Khan and 2006) over fishing and illegal fishing and non- selective fishing by the highly-detrimental enclosure and gill nets caused a decrease in fish population alarmingly. This was clearly reflected in the steady decline to the 20 kg major carp fry production during 2004 and 60-70 kg in 2015 from 2470 kg during 1945 (Fig.2). Instead of such destruction of habitat, species richness has yet not decreased, but their population density is not homogeneous, as indicated by different diversity indices (Table 5).

Suggested Conservation and Management Measures

- Two rubber dams constructed at upstream of Halda River should be removed.
- Newly formed oxbow bend (loop) should not be destroyed and there should be imposition of some regulations to stop harmful anthropogenic activities.
- Most of the sluice gates are now non-functional and not in use, unused sluice gates should be removed immediately.
- Most of the tributaries (12) within four spawning ground in the lower region of Halda for the revival and restoration of fish and other aquatic organisms' habitat need dredging with the consultation of trained hydro-fish-biologists and hydrology-engineers.
- Illegal and detrimental gears (i.e. mono-filament enclosure net and gill net, and so forth) should be banned in Halda and its four adjacent rivers.
- Declaration of closed season, non-fishing from March to July (as per Bangladesh Gazette, 2 July, 2007) should be implemented and maintained also in the Halda linked four rivers and tributaries.
- No industrial/factory/households effluents/wastes should be drained or dumped into the Halda River without proper treatment, and one paper mill established recently near Nandirhat, P.S. Hathazari, and Peking power plant at Hathazari and tanneries (pollution coming through the Madari Khal, Khata Khali, and Khandakia Khal) should be taken under proper regulations.
- Halda origin major carps and other native fish stocking programme should be undertaken for the commercial endangered species. Recently (during 2010, 2011) some major carp fingerlings and sub-adults of Halda origin were stocked in the River Halda, without following the recommendations of Azadi (2005) and Khan and Azadi (2006) with certain ratio for endangered species.
- Halda produced major carps spawn (fries) should be distributed to the public and private hatcheries with reasonable price by government initiative for producing best quality broods which will enhance and promote country's aquaculture and at the same time spawn producers and egg collectors.
- There should be a regular and random vigilance for monitoring all anthropogenic activities by the Government to restore the natural breeding habitat of the river and to stop the illegal fishing and pollution.
- Support and alternative income generating jobs should be provided to the local fishermen affected due to the implementation of year round total fishing banned (Sanctuary) by Bangladesh Gazette (2007 and 2010) declaration.
- Mass-awareness programme among the all levels of peoples about the Halda and its four adjacent river areas by TV, Radio, billboards and leaflets should be undertaken.
- A pragmatic and effective programme should be developed and implemented for the restoration of breeding habitat and conservation of breeding stock of carps.

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