Bangladesh J. Fish. (2021) **33**(2) : 295-304

Plastic pollution in an estuary: A preliminary study on the Rupsha river in southwestern Bangladesh

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Abstract. Plastic pollution is one of the major threats to the biodiversity of coastal mangrove forest Sundarbans. The current research focused on the preliminary assessment of plastics load to benthic biodiversity in a major estuary, the Rupsha in southwestern Bangladesh. Visual studies were conducted at five different sampling sites based on human activities, *viz* Kalibari ghat (S1), Rupsha ferry ghat (S2), Lobonchora ghat (S3), Rupsha bridge ghat (S4) and Putimari ghat (S5 as reference site). Thirteen (13) different plastic types under three categories were identified from the five-study sites. These categories belong to (i) fishing related debris: net, line, buoy, other fishing materials (ii) domestic useable plastics: bottle, bucket, bag/film, foamed polystyrene and polythene, and (iii) category of other types including packet, rope, pipe and shoes. Among all types, packet and polythene were the most abundant in number and both of them were the highest in number in Rupsha ferry ghat (8.67 ± 3.79 for polythene and 9.33 ± 5.86 for packet) whereas lowest in S5 (0.67 ± 0.58 for polythene). Overall, the highest number of plastics (individual items) was identified in S2 station (36 ± 12.5) following to S4 station (24.33 ± 1.53) and lowest at S5 (3.33 ± 0.58). Biodiversity index were also calculated where higher species richness (D) and Shannon index (H) were observed to be higher in S5 compared to other sampling sites.

Keywords: Pollution, Plastics, Rupsha River

Introduction

During the last several centuries since the industrial revolution and astronomically growing human activities have changed the global climate and accelerated pollution to the Aquatic environment consequently creating deleterious effects on aquatic flora and fauna (Derraik 2002, Islam and Tanaka 2004, Vikas and Dwarakish 2015, Villarrubia *et al.* 2018). According to the United Nations Convention on the Law of the Sea (UNCLOS) defined "pollution as the introduction by man, directly or indirectly, of substances or energy into the marine environment, including estuaries, which results or is likely to result in such deleterious effects as harm to living resources and marine life, hazards to human health, hindrance to marine activities, including fishing and other legitimate uses of the sea, impairment of quality for use of the sea water and reduction of amenities" (Tomczak 1984, Williams 1999, Islam and Tanaka 2004, Vikas and Dwarakish 2015).

Plastic pollution in the natural environment has been a serious concern because of its exponential growth and accumulation in the marine environment and therefore, hazardous to the entire ecosystem especially pelagic and benthic communities (Li *et al.* 2016, Barboza and Gimenez 2015, Villarrubia *et al.* 2018). Plastics are synthetic or semi-synthetic biological polymers that are inexpensive, lightweight, robust, durable and corrosion-resistant (Derraik 2002, Thompson *et al.* 2009). Plastic debris usually tends to become brittle, break down into small fragments, and eventually degrade further when exposed to UV radioactivity either under direct sunlight or in seawater, however, complete degradations time in the marine environment remains unknown (Li *et al.* 2016). The versatility of these materials has led to a great increase in their use over the past three decades. Global production of plastic debris increased from around

https://doi.org/10.52168/bjf.2021.33.32

1.5 million tonnes in 1950 to 322 million tonnes in 2015 (Vikas and Dwarakish 2015, Villarrubia *et al.* 2018).

This property of plasticity, often found in combination with other special properties such as low density, low electrical conductivity, transparency and toughness, allows plastics to be made into a great variety of products (Andrews and Subramanian 1992, Vane and Rodriguez 1992). On the other hand, these organic materials are not easily degraded by photo catalysis (Andrady 2011) and other bacterial activities, (Wilcox *et al.* 2015) therefore, make the plastics more durable in nature (Vikash and Dwarakish 2015, Derraik 2002) and persist for years to centuries (Wilcox *et al.* 2015, Barnes *et al.* 2009, Moore 2008) causing toxicants during travelling through aquatic system (Vikash and Dwarakish 2015, Rochman *et al.* 2013) and creates a potential hazard to the environment (Derraik 2002).

Bangladesh has been recognized as an significant nation in the plastic pollution crisis. It has one of the largest river networks in the world and these rivers play a central role in transferring land-based plastic waste to the ocean (Mourshed *et al.* 2017, Proshad *et al.* 2018, Chowdhury *et al.* 2021, Hossain *et al.* 2021). There is a very extensive dense and a large population of approximately 166 million inhabiting in Bangladesh, therefore the plastic materials market size getting bigger day by day. Around 3000 Small Medium Enterprises (SMEs) are involved in the plastic industry and contribute 1% of the national GDP. It has over three thousand small and big plastic industries at present and in the fiscal year 2017-18, plastic products have been recognized as the 12th highest export earning sector in Bangladesh (Mourshed *et al.* 2017, Sarker *et al.* 2020, Hossain *et al.* 2021).

The Rupsha river is a major river in southwestern Bangladesh and a distributary of the Ganges (Fig. 1). It flows by the side of Khulna metropolitan city and connects to the Bay of Bengal through the Pasur river at the Mongla channel (Rahaman *et al.* 2013, Rahman and Islam 2018). Many factories including fisheries, shipyard factories are situated on the bank of this river. This river also supports the livelihood of the people living alongside through different activities. Rupsha river acts as a breeding ground for various freshwater and marine water benthic species. Because of rapid industrialization and urbanization, domestic plastic pollutants rate has been increased enormously. The huge accumulation of plastic and its debris in river banks causes a deleterious effect on biota and river ecosystems and diverse benthic communities. There are not enough studies regarding the plastic scenario in the Rupsha river system, therefore this visual observatory study attempts to find the plastic load and its effect on benthic megafauna in Rupsha river.

Material and Methods

***Sampling site*:** This study has been conducted in Rupsha river and covers around 15 km of the river area. The sampling sites were selected depending on the commercial and human activity performed area's including a reference site (low human activities). The selected station was named as S1: Kalibari ghat, S2: Rupsha ferry ghat. S3: Lobonchora ghat, S4: Rupsha bridge ghat and references site Putimari ghat as S5. Reference site (S5) has been selected considering low or very few commercial and human activities (Fig. 1). The dominant features of the selected site are shown in Table I.

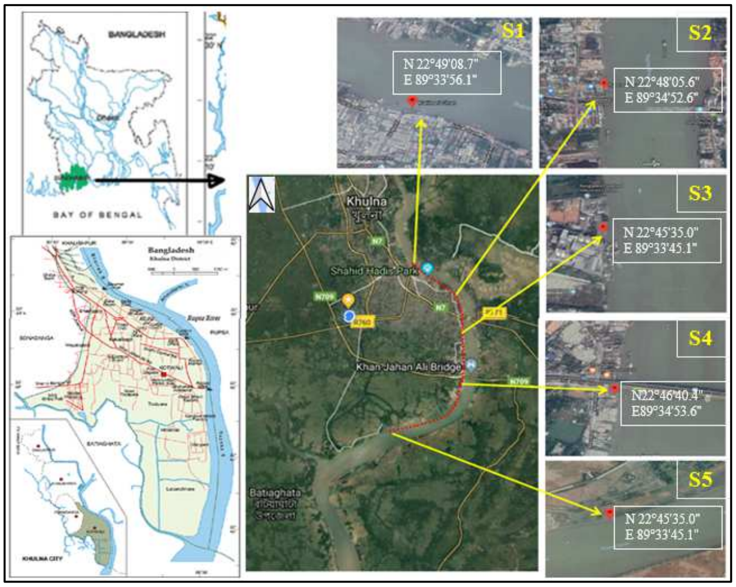


Fig. 1. Sampling sites in Rupsha river including their coordinate.
Map modified from google map and Hossain *et al.* (2016).

Sample collection and preservation

***Visual survey protocol*:** Visual survey transects developed from the Braun-Blanquet abundance scale (Poore 1955, modified by Eriksen *et al.* 2014) method was used to collect benthos specimens. In this method, a $1m^2$ square woody or wired frame was used to collect data. From each site 4 quadrats (From the Rupsha river during low tide) were randomly chosen to record the availability of macro benthos at every 15 days intervals. A visually estimation of the cover of individual species per quadrat was made according to the scale as follows: + (<1%); 1 (1-5%); 2 (5-25%); 3 (25-50%); 4 (50-75%); 5 (75- 100%). Species richness (number of species, S) per quadrat and zonation pattern for each site was also recorded. All the sampling has been taken during low tide for better visualization of benthic fauna and plastic debris, and most of the time sampling were taken from the same place to reduce sampling bias. After collection, the samples were preserved in a plastic bottle with 70% ethanol and taken to the Fish Biology Laboratory of Fisheries and Marine Resource Technology Discipline, Khulna University for further assessment.

***Classification of plastic debris*:** Debris were categorized into three types according to Eriksen *et al.* (2014). The three categories are (i) fishing related debris, i.e. Net, line, buoy and other fishing materials, (ii) domestic useable plastics, i.e. Bottle, bucket, bag/film, foamed polystyrene and polythene (iii) Others including packet, rope, pipe and sandal. Documented plastics pollutants were categorized as their nature and their possible sources were identified.

Table I. Visual observation of environmental Condition of the sampling stations

Sampling Station	Coordinate	Visual environmental/ Condition of the station
Kalibari Ghat (S1)	N 22°49'08.7" E 89°33'56.1"	***Human activities:*** Rice factory, transport, residence. ***Water appearance:*** Turbidity: High, Debris: Plastic, iron, wood structure. ***Soil condition:*** Sandy clay (sandy) with large amount of gravel debris and stone pieces. ***Bank status:*** Artificial structure. ***Pollution status:*** High
Rupsha ferry ghat (S2)	N 22°48'05.6" E 89°34'52.6"	***Human activities:*** Transport, fish arot, fishing activities. ***Water appearance:*** Turbidity: High, Debris: plastic, wood straw, sponge (shola), iron, plant. ***Soil condition:*** Clay loam (Sandy + muddy) with large amount of brick pieces. ***Bank status:*** Stands on artificial structure. ***Pollution status:*** High
Rupsha bridge ghat (S4)	22°46'40.4"N 89°34'53.6"E	***Human activities:*** Trawler, boat, tourism, taking bath, commercial fishing activities. ***Water appearance:*** Turbidity: moderate, Debris: plastic, wood straw, dead organisms. ***Sediment condition:*** Sandy clay (sandy + muddy). ***Bank status:*** both artificial and natural ***Pollution status:*** Moderate
Lobonchora ghat (S3)	22°45'35.0"N 89°33'45.1"E	***Human activities:*** Residence, cement factory, rice stored room, fishing. ***Water appearance:*** Turbidity: Low, Debris: Plastic, sand, large brick and stone pieces, woody structure. ***Soil condition:*** Clay loam (muddy) with large pieces of stones. ***Bank status:*** Stands on artificial structure. ***Pollution status:*** Comparatively lower.
Putimari ghat (S5)	22°44'57.8"N 89°32'03.5"E	***Human activities:*** no or few residences, less fishing ***Water appearance:*** Turbidity: low, Debris: floating plastic bed, wood straw, brick pieces. ***Soil condition:*** Clay loam (muddy). ***Bank status:*** Natural condition ***Pollution status:*** Low

***Biological Diversity Index measurement*:** Two main factors were considered to measure biodiversity index *i.e.* Species richness (D) and Species diversity (Shannon index). The number of species per sample is a measure of richness, meaning more species present in a sample, the 'richer' the sample. This particular measure of species richness is known as D, the Menhinick's index. On the other hand, species diversity differs from species richness in that it takes into account both the numbers of species present and the dominance or evenness of species in relation to one another. As a measure of species diversity, usually calculate the
Shannon index, H.

Thus, species richness $D = \frac{s}{\sqrt{N}} \ldots\ldots\ldots\ldots\ldots (i)$,

where s equals the number of different species represented in your sample, and N equals the total number of individual organisms in your sample.

Shannon Index, $H = \sum(\mathrm{pi})\lfloor \ln \mathrm{pi} \rfloor \ldots\ldots\ldots\ldots\ldots . (ii)$

Where (pi), is the proportion of the total number of individuals in the population that are in species

***Water quality parameters determination*:** Most of the water quality parameters were measured by using the HACH kit, produced by HACH, USA (Model FF-2). Salinity was measured by Refractometer (ATAGO CO. LTD, Japan, model no, Master- T 2312, Salinity range 0-100 g/L), and the temperature was measured using a digital thermometer (China, model no WT-2, Temperature range -20 to 80□C). The water quality parameters were measured twice in a month during sampling.

***Statistical analysis*:** All statistical analyses of species diversity and abundance were performed using IBM SPSS Statistics version 20 and Microsoft excel 2007. The non-parametric Kruskal-Wallis test was done to identify the station-wise variation. Species richness (D) and Shannon Index were calculated by given equation through Microsoft excel. The visual inspection of histogram, normal Q-Q plot and box plot also showed that the data for total abundance was normally distributed. On the other hand, the remaining data on the abundance of individual plastic types were also normally distributed ($p > 0.05$ for both polythene and packet).

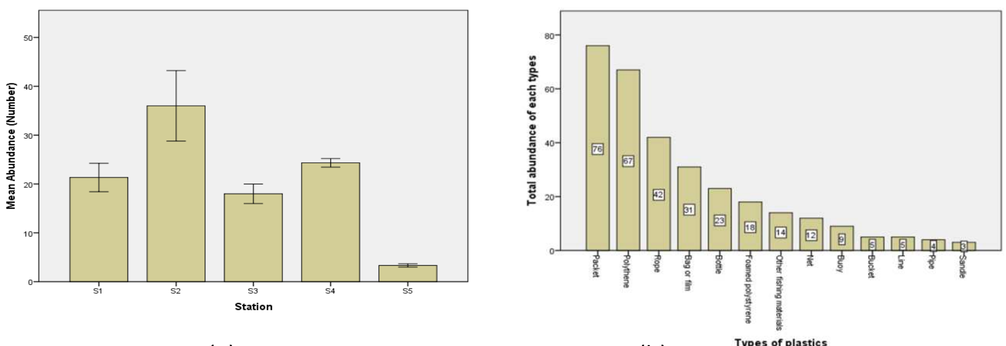
Results

***Major types of plastics and their probable sources*:** From the visual studies, it was observed that most of the plastic were macro plastic because this study didn't analyze microplastics. The plastics items include plastic bottles, fishing net, polyethene, rope, food packets etc. (Table II).

***Abundance and major types of plastics in Rupsha river*:** After 3 months of the experiment, a significant difference was found among the five stations on the total abundance of plastics using one-way ANOVA model ($p < 0.05$, Fig. 2a). From the post-hoc (Games-Howell) tests, it has been seen that the result in S1 station (Kalibari ghat) and S2 station (Rupsha ferry ghat) is not significant with other station. But the post hock testing has revealed that the reference site, S5 station (Putimari ghat) differs significantly from S3 station (Lobonchora ghat), p (0.050) =0.05 as well as from s4 station (Rupsha bridge ghat), p (0.002) <0.05 rather than the S1 and s2 station. At the same time it has been seen that S5 station (M= 3.33, SD= 0.577) has poor abundance than S1 (M= 21.33, SD= 5.033), S2 (M= 36, SD= 12.49), S3 (M= 18, SD= 3.464) and S4 (M= 24.33, SD= 1.528) station indicating high abundance of plastics in S1, S2, S3 and S4 station.

Table II. Different types of plastics items found in Rupsha and their possible sources

Station	Plastic items	Possible source
Kalibari ghat (S1)	Net, Bottle, Polythene, Packet, Rope, Bag	Fishing activities, Industries, Food shops waste, human activities, domestic waste
Rupsha ferry ghat (S2)	Net, Buoy, Bottle, Bag/Film, Polythene, Packet, rope, Car tire	Fishing activities, domestic runoff, Industries, car repair shop, fish arot etc
Rupsha bridge (S3)	Buoy, packet, bottle, beg, polythene	fishing boat, tourism activities, food shop, current flow
Lobonchora ghat (S4)	Packet, polybag, drinks bottle, rope	Shop, vegetable market, domestic runoff, Rice and cement factory
Putimari ghat (S5)	Bottle, polythene, packet	Nearby household, current flow, fishing



(a) (b)

Fig. 2. Abundance of plastic load in different sites of Rupsha river (a) and major type of plastic items observed during the observation (b)

***Abundance of benthic species in Rupsha river*:** From the visual observation, there were 13 different benthic species were identified from the study site. Among them, *Cornu aspersum* and *Rhithropanopeus harrisii* are the major abundance in the river system. The observed species were fish; (*Bagarius bagarius*, *Glossogobius giuris*, *Puntius sarana*, *Pseudapocryptes elongates*); crabs (*Paraseasarma pictum*, *Uca anmulipies*, *Rhithropanopeus harrisi, Ocypode pallidula*); snails (*Ellobium pyramidale, Cornu aspersum*, *Neripteron auriculatum*, *Hedleyella falconeri)* and polychate (*Polydora websteri).* The highest mean benthic individual observed in Putimari ghat (62.67±21.73) and the lowest was found in Kalibari ghat (7.00±3.61) following to Rupsha ferry ghat (Table III).

Table III. The abundance of benthic species under Rupsha river station of 0.01 < 0.043 < 0.05

Treatment	N	Mean±SE	95% Confidence interval for mean		Minimum	Maximum
			Lower Bound	Upper Bound		
S1	3	7.00±2.08	-1.96	15.96	4	11
S2	3	18.33±0.88	14.54	22.13	17	20
S3	3	14.33±2.40	3.99	24.68	11	19
S4	3	27.67±10.39	-17.07	72.40	7	40
S5	3	62.67±12.54	8.68	116.66	38	79

***Biodiversity index*:** Species richness (D) and species diversity (Shannon Index) are shown in Fig. 3. Significantly higher species abundance were observed in references site. Similarly higher Shanon diversity index was observed in S5.

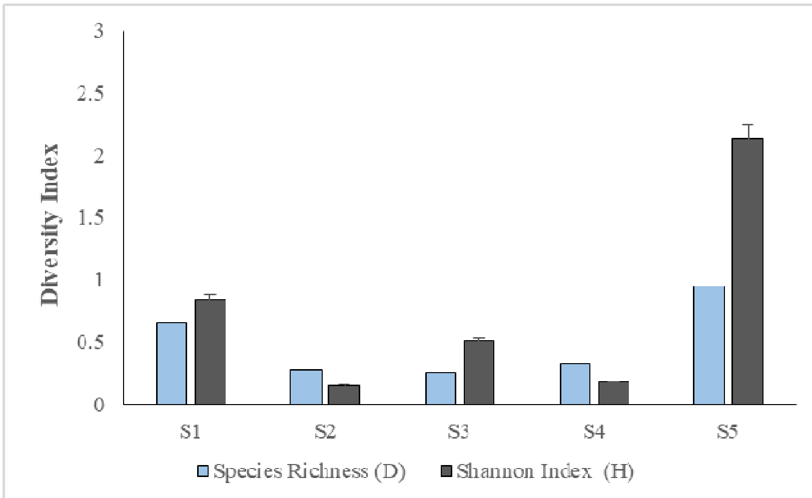


Fig. 3. Diversity index of benthic macro fauna in Rupsha river. Blue line indicate Species richness (D) and black line indicate species diversity (H).

***Water quality parameters*:** Major water quality parameters were shown in Table IV. There was no significant difference in water quality among the study sites. pH, salinity, DO and temperature among the study site ranges respectively at 7.5- 7.9, 15-20 ppt, 5.0-62 mg/l and 22.5-25 °C. Maximum Alkalinity and NO_3-N were 177.8±22.0 mg/l and 6.2-6.5 mg/l respectively.

Table IV. Water quality parameters of sampling sites in Rupsha river during experimental periods

Sampling sites	pH	DO (mg/L)	Salinity (ppt)	Temperature (°C)	Alkalinity (mg/L)	Transparency (cm)	NO_3-N (mgL^{-1})
S1	7.7-7.95	5.3-5.7	15.5-19.5	22.8±2.5	162.4±17	17-22	5.9-6.5
S2	7.5-7.80	5.0-5.5	15.5-20.0	23.1±3.5	177.8±22	16-23	6.2-6.5
S3	7.8-7.90	5.5-6.0	16.0-20.5	22.5.8±2.7	169.4±18	17-22	6.2-6.5
S4	7.7-7.9	5.4-5.8	15.0-15.5	23.0.8±2.0	165.54±24	17-23	5.8-6.1
S5	7.4-7.8	5.7-6.2	15.5-20.0	22.5.8±3.0	170.2±19	18-24	5.5-5.8

Discussion

Khulna is the 3rd largest coastal district of Bangladesh located on the bank of two major rivers Rupsha and Bhairab and again these rivers directly have a connection with the Bay of Bengal through Poshur river (Rahaman *et al.* 2013). Because of rapid industrialization and easy access to the sea port Mongla, the habitation increasing indiscriminately in this city. As a result, domestic uses of poly bag and other plastic commodities are increasing rapidly and ultimately settle down to the Rupsha river bed. In the present study, it has been found that the major items of plastics come from domestic waste, market place, industry, fishing boats etc. The similar scenario has been observed in the Padma and the Meghna River (Chowdhury *et al.* 2021), Buriganga river (Ahmad *et al.* 2010), Rupsha river (Rahaman *et al.* 2013, Bir *et al.* 2015) and Mouri river in Khulna (Kamal *et al.* 2007).

The present study has revealed that benthic species abundance as well as the consequences of plastic pollution in shoreline areas of the Rupsha river system. This study has only focused on the impact of plastic pollution on benthic diversity. But this is not the only reason for this change. There are too many cumulative causes, like water pollution, fishing activities, industrial discharge, and other agricultural and domestic pollutants that might be responsible for the changes. As the Rupsha is one of the most important Rivers in Khulna city therefore it has the huge possibility to incorporate pollutants from different sources. Almost similar type of benthic fauna has been observed by Hossain et al., (2016) and Kamal *et al.* (2007) at Mouri river, Khulna. The benthic species differ in respect of the abundance of plastic throughout the station. The highly human activities and industrial areas like Rupsha ferry ghat (S2) and Rupsa bridge (S3) having more load of the pollutant therefore, the species richness and diversity is lower than the references site.

The abundance of several kinds of benthic species were found to vary from station to station of Rupsha river system. Plastic is not the only reason behind the variation in species richness and diversity but also several other factors works here for changing benthic specie like sediment condition, water temperature, salinity, DO, pH, hardness, alkalinity etc. Sometimes these factors are positively or negatively correlated with benthic species in river system. Rupsha river is a very dynamic river system directly connected with the Bay of Bengal therefore, seasonal changes of hydrodynamics have been found in this river system. In this study, data has been monitored only for three months (Feb-April) that doesn't reflect the overall water quality parameter of the Rupsha river. However, some major hydrodynamics was found to be similar to the previous studies (Rahaman et al., 2013, Bir et al., 2015, Islam et al., 2018).

Plastic pollution is not only the problem of Rupsha river but also the problems of almost all aquatics bodies in Bangladesh. The huge load of the plastic items in river bed reduced the river depth causing deleterious effects on different migratory fishes and many benthic species and depleting the ecosystem of the river. The rapid development of the plastics industry is having a multiplier consequence on numerous important sectors of Bangladesh. The Bangladesh Government should give priority to establish suitable management and disposal strategies of plastic items. Although there have numerous challenges to overcome this problem including the proper management of plastic waste and the negative environmental image of plastic industries. Public awareness also is an important step to control the plastic pollution from our aquatic system. So, we should be enough sensible about using plastic materials and it will be excessive if we exclude using plastic materials from our humanity.

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(Manuscript Received: 11 November 2021)