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Effects of ship-breaking activities on the abundance and diversity of macrobenthos in Sitakundu Coast, Bangladesh

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Abstract. *Lipi JA, Noman MDA, Hossain MB, Abu Hena MK, Idris MH. 2020. Effects of ship-breaking activities on the abundance and diversity of macrobenthos in Sitakundu Coast, Bangladesh. Biodiversitas 21: 5085-5093.* To articulate the ecological processes or anthropogenic impacts, it is necessary to explore various distributional patterns of benthic communities. The study was conducted to investigate the variability of macrobenthos between a ship braking and non-ship-breaking area along the Sitakunda coast, Chittagong, Bangladesh. This is the first comprehensive study that addresses the effects of ship-breaking activities on the variability of benthic communities in the study area. Macrobenthos were sampled from two different regions namely Bhatiary (ship-breaking area) and Banshbaria (non-ship-breaking area/reference area) in two different time periods (April and July) for comparative analyses. During the study period, Polychaeta was the most dominant group comprising 60% of the total macrobenthos all over the study area. Macrobenthos abundance and diversity demonstrated strong spatial variability. The mean abundance varied from 3799.75±3452.28 ind./m^2 to 4107.25±2743.6 ind./m^2 from the ship-breaking to non-ship-breaking area. Similar to macrobenthos abundance, the diversity index (H') (varied between 2.45 and 1.85), species richness (D) (varied between 1.99 and 1.04), and the number of taxa (varied between 17.25 and 9.25) were higher in the non-ship-breaking area compared to the ship-breaking area. Multivariate analyses, nMDS, and CCA plot showed a distinct grouping for different location. Besides, the diversity indices of the Polychaeta community, and the presence or absence of several pollution indicator taxa revealed that Bhatiary (the ship-breaking area) was confronting deleterious effects of ship-breaking activities.

Keywords: Macrobenthos, rainfall, ship-breaking activities, Sitakundu coast, spatial distribution

INTRODUCTION

Seashore comprises the majority of the macrobenthic species (Herman et al. 1999; Mulik et al. 2020) and those species play a vital role in food web by forming a major link between primary producers and higher trophic levels while regulating organic matter decomposition and nutrient cycling (Lin et al. 2020). Macrobenthic invertebrate species are known as ecosystem engineers because they continuously influence the physical parameters, the flow of waters, and changing the environments (Gogina and Zettler 2010). They provide a linkage among substratum, seabed, and water column predators (Gray and Elloitt 2009). All living beings, microscopic to macroscopic, assume a tremendous job in adjusting the biological system. Loss or extinction of any assemblages of living beings hampers the functioning of that biological system (Hossain et al. 2013). Benthic communities are often used as biological indicators because they can provide information on environmental condition either due to the sensitivity of single species (indicator species) or because of some general feature that makes them integrate environmental signals over a long period of time (Tagliapietra et al. 2010; Netto et al. 2018). Biological hazard analysis is necessary for scientifically authentic assessment of the environment. This way may contribute to the conservation and the regulation of nature from anthropogenic affects (Chen et al. 2013). By knowing these, macrobenthos has become the subject of many studies all over the world even in Bangladesh.

The south-eastern coastal area of Bangladesh is highly productive and possesses a huge amount of marine and coastal resources. In recent years, this area is losing its norm because of different anthropogenic factors and industrial pressure. Ship-breaking, repairing, demolition, and various kinds of related activities are increasing severely in this area. Ship-breaking and Repairing Industries (SBRI) are key sources of cheap iron and steel, for construction and other development purposes. In most of the developing countries, ship-breaking activities are currently carried out and the level of activity in Bangladesh is 23% in terms of light displacement ton (LTD) from 1994 to 2009 (NCSG 2011; Abdullah et al. 2013). But, the matter of fact that SBRIs are strong sources of hazardous contaminants along the coastal seashore, which is the most, diversified area of the world. Unfortunately, in comparison with other studies, ship-breaking activities and its impact on the coastal zone received very lower attention from the previous researchers of Bangladesh. But, this area plays a significant role in the country's economy. Besides, a huge portion of the country's total fisheries production comes from this area every year. Though there are many types of research on the benthic community, diversity and abundance (Khan et al. 2007; Hossain et al. 2009; Asadujjaman et al. 2012; Abu Hena et al. 2013; Hossain et al. 2013; Islam et al. 2013), a very few research (Sarker et al. 2016) held on the assessment of pollution, and there are no records of research on this issue in Sitakundu.

Therefore, by considering the knowledge gap and importance of macrobenthos and their habitat, the present investigation was undertaken to set baseline information on the spatiotemporal variability of macrobenthos community between a ship-breaking area and a non-ship-breaking area (reference area) along the Sitakundu coast of Bangladesh. Using the variability of macrobenthos diversity indices and several indicator taxa, this study may provide preliminary information about macrobenthos and habitat condition for the future research to study the in-depth deleterious effect of ship-breaking activities in this area.

MATERIALS AND METHODS

Study area

The study areas were separated into ship-breaking area and reference area for comparative analysis of macrobenthos abundance (Figure 1). The ship-breaking area namely Bhatiary and non-ship-breaking area namely Banshbaria along Sitakundu coast. According to (YPSA 2005) there are 24 ship-breaking yards in this area and the area extending from over 14 km along this area and more than 100 companies are involved in the ship-breaking business (YPSA 2011). Two sampling locations from ship-breaking area (L1, L2) and two from the reference area (L3 and L4) were selected during April and June in 2016 (Table 1). Three replicate samples were collected from the intertidal area at each station to determine the physical parameters and macrobenthos abundance.

Sample collection

Intertidal sediments were collected during the low tide period using a mud corer having a mouth area of 0.01 m^2. In order to ensure the data accuracy, three replicate samples were collected from each station. Collected sediments diluted gently in the water, and the residues retained by sieving through a 500-µm mesh size net. Collected residues were promptly preserved in 10% formalin solution and transferred to the laboratory. To enhance the visibility of benthic fauna, a modest quantity of "Rose Bengal" (2-3 ml from a solution of 200 mg Rose Bengal/L^{-1} distilled water) was added to the sediment sample in the laboratory. Benthic fauna was identified as the lowest possible taxon through an optical microscope (Model No. XSZ 21-014DN, China) according to the characteristics described by Al-Yamani et al. (2012). Meanwhile, the identified fauna was quantified and calculated as the total number of inds./m^2. Water temperature (°C), salinity (psu), and pH were measured using Centigrade thermometer, Refractometer (INDEX, Model no. REF201) and Digital pen pH meter (HANNA Instrument, Model No. H-196107).

Table 1. Study area and the coordinates of sampling locations

Name of area	Sampling location	Latitude	Longitude
Ship-breaking area (Bhatiary)	L1	22°23′58.4″N	91°44′28.2″E
	L2	22°25′56.64″N	91°43′47.64″E
Reference area (Banshbaria)	L3	22°32′24.2″N	91°39′56.4″E
	L4	22°32′54.5″N	91°39′52.1″E

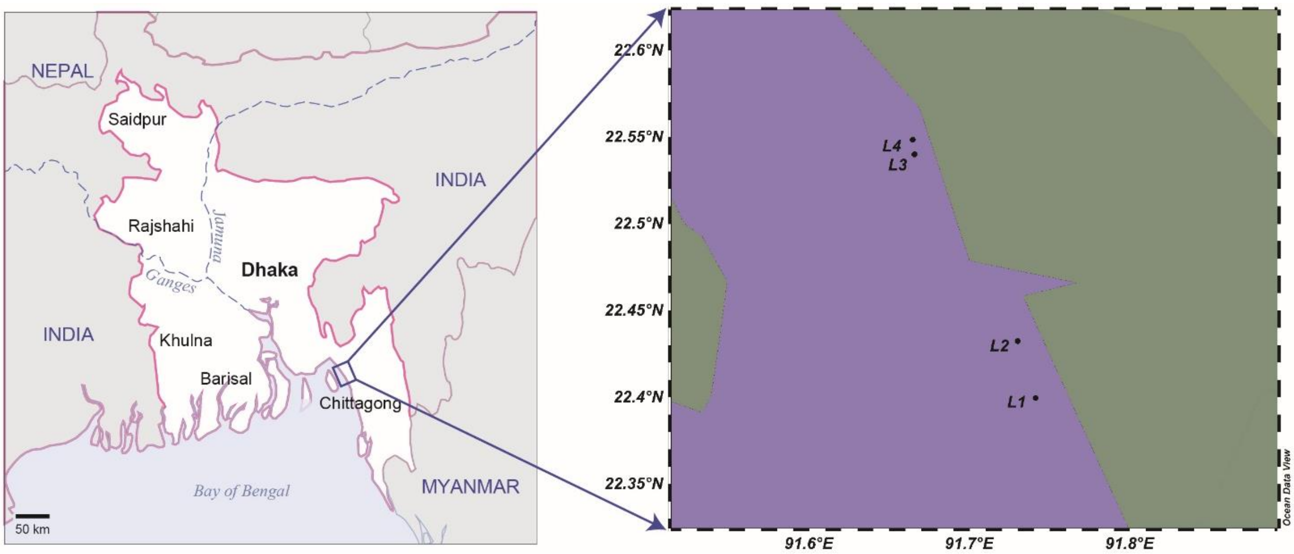

Figure 1. Map of Sitakundu Coast, Bangladesh showing sampling locations. L1 and L2 indicates ship-breaking area and L3 and L4 indicates reference area

Data analysis

After counting each group of macrofauna, total abundance, mean abundance, and standard error (SE) were calculated from the estimates of each replicate sample from respective station. Macrofaunal diversity, evenness, and richness were discerned using the Shannon-Wiener index (*H′*), Pielou's evenness index (J′), and Margalef's richness index (D) respectively. Square root transformed Bray-Curtis similarity-based non-metric multidimensional scaling (nMDS) with visualizing cluster overlay (with all replicate samples) was analyzed through PRIMER software (Version 6). In addition, Canonical Correspondence Analysis (CCA) was performed to show the relationship between species composition and physical factors using Past v 3.0 software.

RESULTS AND DISCUSSION

Physical parameters

The physical parameters seem more or less similar in the ship-breaking and reference area. The water temperature varied from 28.33-30.3°C in the ship-breaking area and 31.67 to 35.33°C in the reference area. It was found that the pH of the examining area was alkaline in nature wherein it was practically similar in most of the stations bearing a range of 8-8.8 in the ship-breaking area and 8.03-9.8 in the reference area. Besides, the salinity also didn't show much variability between these two areas. But, salinity showed a notable variation in two different sampling periods. Because of heavy rainfall and surface runoff, the salinity ranged from 0.33 to 0.67 psu in June, whereas in April it ranged between 10.17-10.67 psu in both areas. Similarly, the higher water temperature was estimated during the April (average temperature 31.62±3.34°C) and lower during June (average temperature 31.06±1.01°C) (Figure 2).

Variability of macrobenthos distribution

The macrofauna of the present study was identified to family. In the ship-breaking area, a sum of 15 taxa (families) of benthic fauna found during the study, whereas a total of 27 taxa of benthic fauna were identified from the reference area. The current study yielded an aggregate of 15432 inds./m^2 with an average abundance of 3799.75±3452.28 inds./m^2 from all stations of ship-breaking area. On the other hand, a total number of 16429 inds./m^2 of macrobenthos were recovered from all stations of the reference area with an average abundance of 4107.25±2743.6 inds./m^2. However, the abundance of macrobenthic fauna demonstrated a notable variability between the sampling period. The average abundance in April was around five folds higher than June bearing 6541.67±1292.25 and 1275.00±736.04 inds./m^2 respectively.

Seven major groups of macrobenthos were identified from the entire study. The composition of macrobenthic assemblage didn't show much variability between the ship-breaking and non-ship-breaking areas (Figure 3). Polychaeta was the prevailing group in both regions. At the ship-breaking area, Polychaeta contained 60% of total macrobenthos and followed by Bivalvia and Decapoda bearing 32% and 5% respectively (Figure 3). In the reference area, the group Polychaeta also indicated similar distribution bearing 62% of total abundance and followed by Amphipoda (16%) and Bivalvia (11%) (Figure 3). Capitellidae and Psammobidae dominated the ship-breaking area contributing 34% and 31% respectively whereas Nephtyidae and Hyperidae were the dominant taxa at the reference area contributing 11.76% and 11.16 % respectively.

Variability of macrobenthos diversity indices

Diversity indices showed significant differences between the areas. During the study period, higher values of diversity indices were observed in April while in June the diversity was lower. The number of taxa, S-W diversity index, and Margalef's species richness showed much variability between two regions. The number of taxa shifted from 21 to 14 at the reference area while it ranged from 10 to 8 at the ship-breaking area. The diversity was higher as well in this area. The diversity value changed from 2.49 to 2.55 at the reference, whereas at the ship-breaking area it varied from 1.5 to 1.85. Similarly, the Margalef's species richness value depicted that the richness was lower at the ship-breaking area than the reference area. The species richness ranged from 1.68 to 2.29 in the reference area while at the ship-breaking area the richness varied from 0.99 to 1.11 (Table 2).

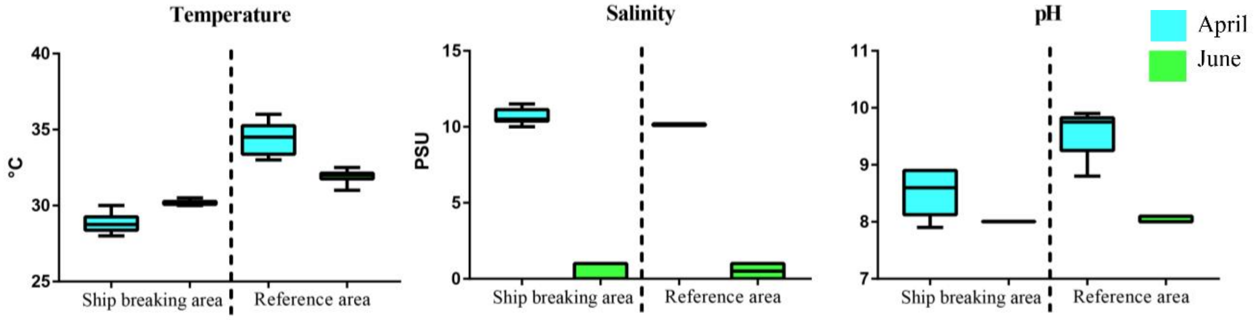

Figure 2. Distribution of physicochemical parameters in the study area, Sitakundu Coast, Bangladesh, during April and June

Table 2. Diversity indices examined from the ship-breaking and reference area in both seasons (A-April; J-June)

Diversity indices	Ship-breaking area				Reference area			
	AL1	**AL2**	**JL1**	**JL2**	**AL3**	**AL4**	**JL3**	**JL4**
Taxa (S)	10	11	8	8	21	19	14	15
Shannon (*H'*)	1.69	1.5	1.84	1.85	2.52	2.55	2.26	2.49
Evenness (J)	0.54	0.41	0.79	0.79	0.59	0.67	0.68	0.79
Margalef (D)	1.06	1.11	1.018	0.99	2.29	2.05	1.68	1.97

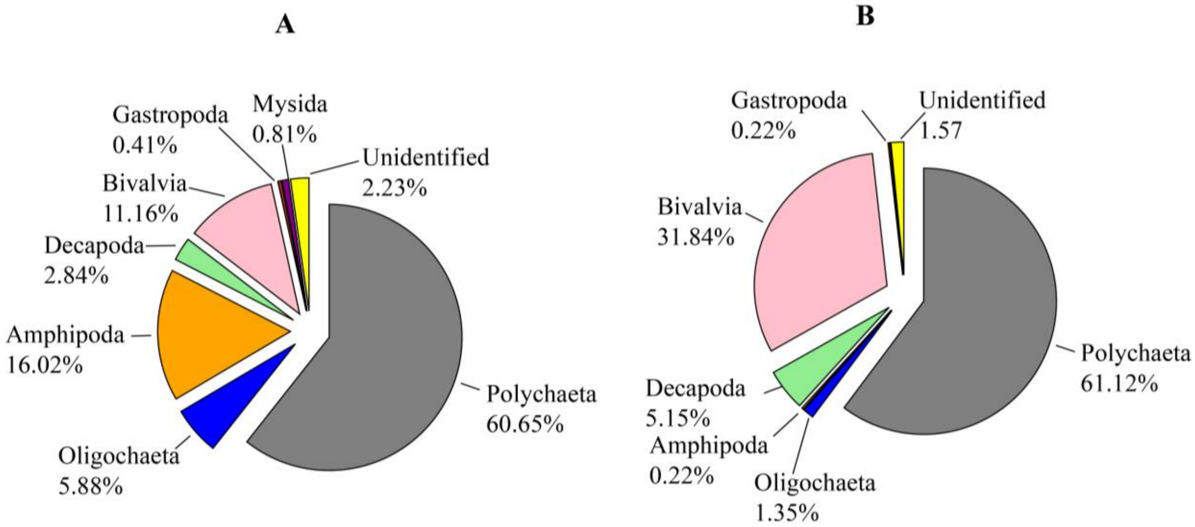

Figure 3. Percentage composition of the macrobenthic groups in both the reference (A) and ship-breaking area (B)

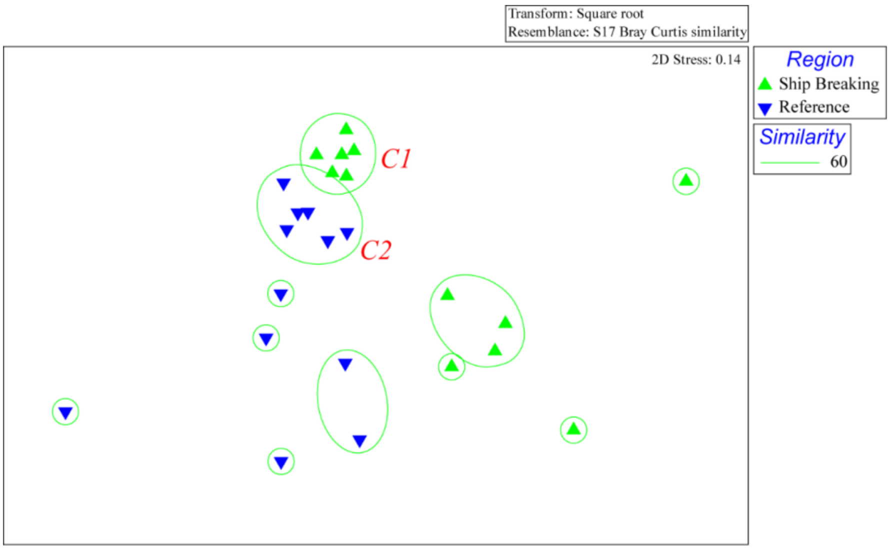

Figure 4. nMDS plot with overlying cluster showing the clustering of samples in different areas and different seasons

Relationship between macrobenthos and physical parameters

The nMDS plot is showing the cluster of all the samples from the whole study. At a 60% degree of similarity all the samples from the ship-breaking and reference area showed distinct grouping with each other. Two major clusters were found at 60% similarity, which is indicated as C1 and C2 in Figure 4. Most of the samples from the reference area made a distinct cluster (C2). Similarly, the samples from the ship-breaking area made a different cluster (C1). However, from the nMDS plot, it is clearly visible that there was significant variability between two regions (Figure 4).

CCA analysis between the physical parameters and taxa composition revealed that salinity was the most significant factor ($P<0.05$) in this study. CCA triplot was projected from the first two axes of CCA, which comprises respectively 68.3% and 31.7% of the samples. From the CCA plot, four groups of taxa were differentiated based on the taxa distribution and their relationship with physical parameters (Figure 5). The group 'A' taxa were positively correlated with temperature and those were mainly distributed in reference area (L3, L4) during April. All the stations during June comprised similar species composition and segregated in group 'B'. Those taxa were positively correlated with temperature and negatively correlated with salinity and pH. Capitellidae and Psammobidae were highly abundant in the ship-breaking area during April and showed a negative relationship with temperature (Group C). Some of the macrobenthic taxa didn't show any relationship with the physical parameters (Group D). However, it is observed from the CCA analysis that macrobenthic taxa composition differs from the region based on their preferred environmental parameter. Though species composition was almost similar in both of the area during June, it differs in April and non-ship-breaking area was a promoter in this aspect.

Pollution indicator groups

Different groups of polychaete have been used for assessing the overall “health” of the benthic community (Dean 2008). Among them, the capitellids (such as *Capitella capitate*) act as the positive indicator of the detrimental environment, which means their presence reveals the poor environmental condition (Dean 2008; Belan 2013). On the other hand, members of the family Lumbrinidae, Maldanidae, Sabellidae, and Terebellidae negatively respond to the harmful condition, that means, their absence denotes the poor environmental condition (Belan 2003; Olsgard et al. 2003; Dean 2008). We observed, both the positive indicators and the negative indicators showed similar distribution in the reference and ship-breaking area during June. However, in April, maximum abundance of Capitellidae recovered from the ship-breaking area, which was several times higher than the reference area (Table 3, Figure 6). Besides, the negative indicators Lumbrinidae, Maldanidae, Sabellidae and Terebellidae were also found in the reference area during April.

Discussion

A total of 28 taxa of macrobenthic fauna were identified during the study period comprising 15 taxa from the ship-breaking area and 27 taxa from the reference area. Seven major groups of macrobenthos were identified wherein Polychaeta was the most dominant group comprising more than 60% of the total macrobenthos on an average. It is evident from most of the regional macrobenthos study that Polychaeta dominated this area all the year round (Khan et al. 2007; Asadujjaman et al. 2012; Noman et al. 2018). The abundance of macrobenthos was much higher in April (6541.67±1292.25 inds./m^2) in this area than June (1275±736.04 inds./m^2).

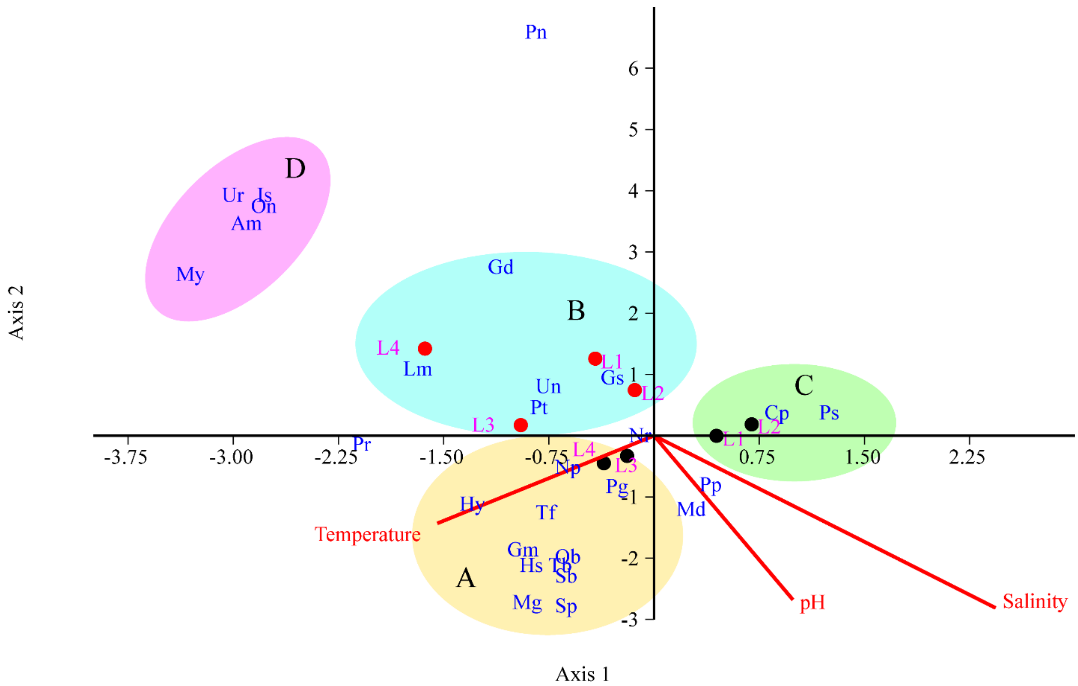

Figure 5. CCA triplot showing the relation between station, environment and macrobenthos. (black dots- April, red dots- June; Am-Ampeliscidae; Ps-Psammobidae; Cp-Capitellidae; Pt-Portunidae; Gm-Gammaridae; Gs-Gastropod larvae; Gd-Goniadidae; Hs-Hesionidae; Hy-Hyperidae; Is-Isaeidae; Lm-Lumbrinereidae; Mg-Magelonidae; Md-Maldanidae; My-Mysidae; Np-Nephtyidae; Nr-Nereididae; On-Onuphidae; Ob-Orbiniidae; Pr-Paraonidae; Pn-Penaeidae; Pg-Pilargiidae; Pp-Priapulidae; Sb-Sabellidae; Sp-Spionidae; Tb-Terebellidae; Tf-Tubificidae; Ur-Urothoidae; Un-Unidentified)

Table 3. Macrobenthic taxa (ind./m^2) identified from the present study

Name of taxa	AL1	AL2	AL3	AL4	JL1	JL2	JL3	JL4	Mean	SE
Ampeliscidae	0.00	0.00	0.00	0.00	0.00	0.00	33.33	100.00	16.67	12.60
Capitellidae	2233.33	2500.00	500.00	866.67	266.67	200.00	233.33	33.33	854.17	342.49
Gammaridae	0.00	0.00	333.33	66.67	0.00	33.33	0.00	0.00	54.17	40.79
Gastropod larvae	0.00	33.33	33.33	0.00	0.00	0.00	0.00	33.33	12.50	6.10
Goniadidae	0.00	0.00	0.00	66.67	66.67	0.00	0.00	33.33	20.83	10.80
Hesionidae	0.00	0.00	66.67	100.00	0.00	0.00	0.00	0.00	20.83	14.00
Hyperidae	0.00	0.00	733.33	833.33	0.00	0.00	233.33	100.00	237.50	122.87
Isaeidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	166.67	20.83	20.83
Lumbrinereidae	0.00	66.67	466.67	533.33	200.00	266.67	566.67	133.33	279.17	77.14
Magelonidae	0.00	0.00	33.33	0.00	0.00	0.00	0.00	0.00	4.17	4.17
Maldanidae	33.33	133.33	166.67	200.00	0.00	0.00	0.00	0.00	66.67	30.21
Mysidae	0.00	0.00	0.00	0.00	0.00	0.00	100.00	33.33	16.67	12.60
Nephtyidae	233.33	366.67	700.00	700.00	33.33	0.00	466.67	66.67	320.83	100.78
Nereididae	333.33	366.67	400.00	566.67	100.00	100.00	66.67	0.00	241.67	71.20
Onuphidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	33.33	4.17	4.17
Orbiniidae	0.00	0.00	33.33	100.00	0.00	0.00	0.00	0.00	16.67	12.60
Paraonidae	0.00	0.00	100.00	33.33	0.00	0.00	133.33	0.00	33.33	18.90
Penaeidae	0.00	0.00	0.00	0.00	66.67	33.33	0.00	0.00	12.50	8.77
Pilargiidae	133.33	166.67	300.00	366.67	0.00	0.00	33.33	100.00	137.50	48.16
Portunidae	100.00	100.00	66.67	100.00	0.00	0.00	133.33	33.33	66.67	17.82
Priapulidae	900.00	733.33	366.67	1000.00	0.00	0.00	133.33	0.00	391.67	150.76
Psammobidae	800.00	3700.00	1466.67	300.00	0.00	233.33	66.67	0.00	820.83	448.01
Sabellidae	0.00	0.00	33.33	33.33	0.00	0.00	0.00	0.00	8.33	5.46
Spionidae	0.00	0.00	33.33	0.00	0.00	0.00	0.00	0.00	4.17	4.17
Terebellidae	0.00	0.00	33.33	133.33	0.00	0.00	0.00	0.00	20.83	16.59
Tubificidae	200.00	0.00	266.67	533.33	0.00	0.00	133.33	33.33	145.83	66.05
Urothoidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	33.33	4.17	4.17
Unidentified	100.00	33.33	133.33	100.00	33.33	66.67	33.33	100.00	75.00	13.73

Note: A: April; J: June; L: Location; SE: standard error

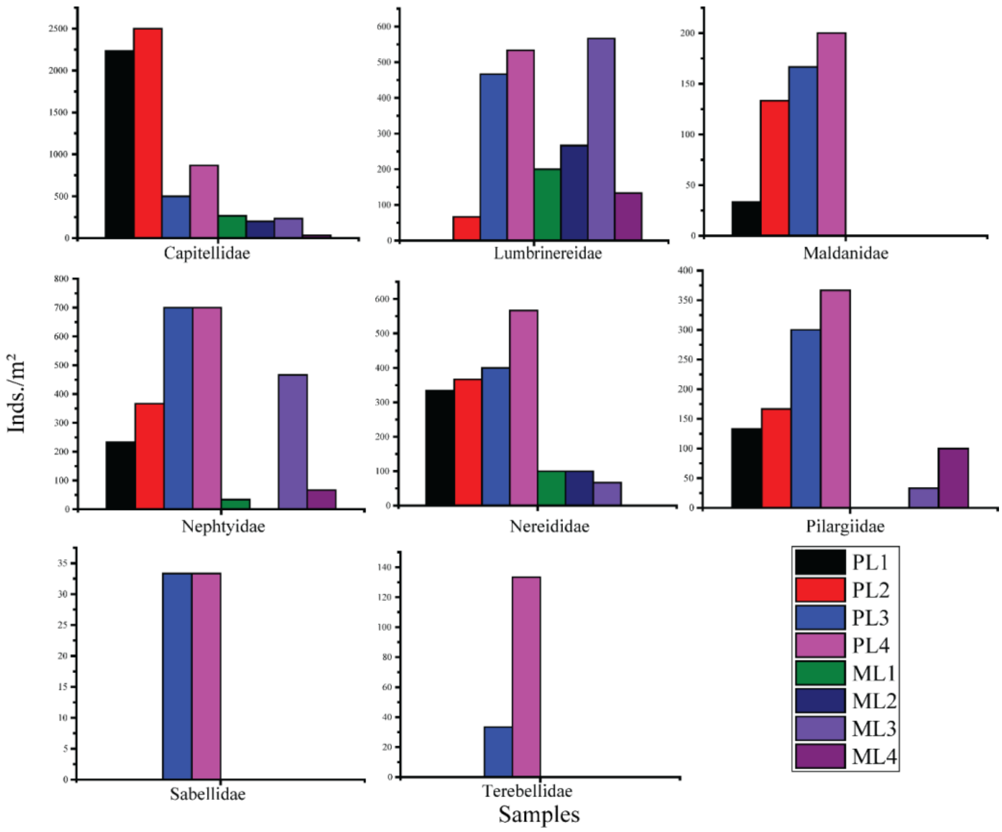

Figure 6. Variability of macrobenthic indicator taxa in the present study

Similarly, the number of taxa and macrobenthos diversity (*H′*) was also maximum during April. It was reported that macrobenthos abundance decreases in the monsoon because of rainfall (Hossain et al. 2009). In this region, the monsoon starts with the month of June and the amount of rainfall is relatively higher. Our CCA analysis showed that salinity was the major factor for the variation of abundance between two sampling periods, which revealed the effects of low salinity causing terrestrial runoff and rainfall over macrobenthos community. In association with these findings, most of the regional studies demonstrated that rainfall influences the macrobenthos community (Hossain 2009; Kumar and Khan 2013; Noman et al. 2018).

The mean abundance of macrobenthos was higher in the reference area than the ship-breaking area bearing respectively 4107.25±2743.6 inds./m^2 and 3799.75±3452.28 inds./m^2. The diversity indices values were higher at the reference area than the ship-breaking area. The S-W diversity index value at the ship-breaking area varied from 1.49 to 1.85 while in the reference area it was higher and ranged between 2.48 to 2.55. Noman et al. (2018) found the S-W index ranged from 1.05 to 1.67 while Khan et al. (2007) reported that the diversity varied from 1.20±0.23 to 1.49±0.753. Similarly, Hossain et al. (2013) observed in Hatiya and Nijhum Dweep island diversity fluctuated from 1.22 to 1.49. Most of the studies showed that the S-W index value didn't show much variability in their findings, whereas we observed significant differences of S-W index within the two-study area. Similarly, the species richness value was also higher in the reference area. There are supposed to be a noteworthy change in benthic community parameters especially their abundance, biomass, dominance and diversity, when the community experience stress due to harmful environmental condition (Dean 2008). Therefore, we hypothesized, the shipbreaking area was influenced by deleterious materials, which might have lowered the abundance, diversity, and richness of macrobenthos in this area. Besides, Sarker et al. (2016) reported the species richness varied from 2.21±0.43 to 1.36±0.11 respectively in less polluted Bakkhali estuary and extremely polluted Meghna estuary, which supports our findings and the prediction. The presence or absence of macrofauna and variability of diversity indices (Rodrigues et al. 2017) especially S-W diversity index, species evenness index (Li et al. 2018), and species richness (Margalef 1958) can be a measure of pollution over benthic community.

Moreover, the Polychaeta community can act as a significant ecotoxicological testing component because of their short life cycle, smaller size, and substantial contribution to any benthic community (Dean 2008). We observed the diversity indices of Polychaeta community varied greatly between ship-breaking area and reference area. Higher abundance, number of taxa, diversity, and richness of Polychaeta recorded in the reference area. However, in June, all these indices were almost similar in both areas (Figure 7). However, it's a challenging task to assign a specific benthic species as the indicator of deteriorated condition. Different geographical settings react differently to detrimental ecological conditions possessing their own arrangement of positive indicators and negative indicators (Dean 2008). In the Sitakundu coast, we found high abundance of Nephtyidae, Neridiae, and Pilargiidae in the reference area, which might be the negative indicators of pollution in this area (Figure 6). However, the response of indicator taxa and their seasonal variation supports our hypothesis that the benthic community of the ship-breaking area was confronting severe unsettling and deleterious effects, and the rainfall in June alleviated the detrimental effect of ship-breaking activities.

Besides, at the 60% similarity levels the entire cluster showed the distinct grouping of regions. Cluster C1 included the samples from the ship-breaking area while the cluster C2 showed the grouping of the reference area. Sampling stations of different zones forming distinguished groups elucidate the alteration in species composition and abundance (Pravinkumar et al. 2013; Khan et al. 2017). However, similar to the nMDS analysis, CCA triplot also showed that all samples from the June accumulated on the same axis. Besides, based on our findings from CCA analysis, salinity is a significant factor shaping the species composition, which depicted that rainfall might have alleviated the detrimental effect of ship-breaking activities. But, we couldn't identify any specific factor, which was significantly responsible for the variation of macrobenthos between ship-breaking area and reference area. Therefore, it can be predicted from our study that the physical factors were not responsible for the variation of macrobenthos abundance, diversity, and richness between the reference area and the ship-breaking area. There must be other factors, which influenced the abundance of macrobenthos in the ship-breaking area.

This is might be the effects of various kinds of abnormalities produced by the ship-breaking activities in this area. Hossain and Islam (2006) found that elevated turbidity, total suspended solids, and total dissolved solids reflect the physical disturbance in the ship-breaking area. According to Siddiquee (2004); Apeti et al. (2012), during ship-breaking exercises trace metals, are yielded and discharged results increased concentrations with respect to permissible values or standard limits. Shipyard soil reported to be contaminated with hazardous radioactive materials such as radium (226Ra), thallium (232Th), and potassium (40K) due to shoreline ship-breaking activities (Hossain et al. 2010). Moreover, ship-breaking activities also affect the availability of organic materials in the soil (Rubaiyat et al. 2013). All these combined factors might be the possible reason for the low abundance of macrobenthos in the ship-breaking area (Siddiquee 2004). Because of resource limitation, we couldn't include the organic and inorganic pollutants in our study. Therefore, we cannot precisely hypothesize which pollutants were responsible for the low abundance of macrobenthos in the ship-breaking. Hence, further research is recommended in this area including all the pollutants to find out the toxicological effects of ship-breaking on macrobenthic community.

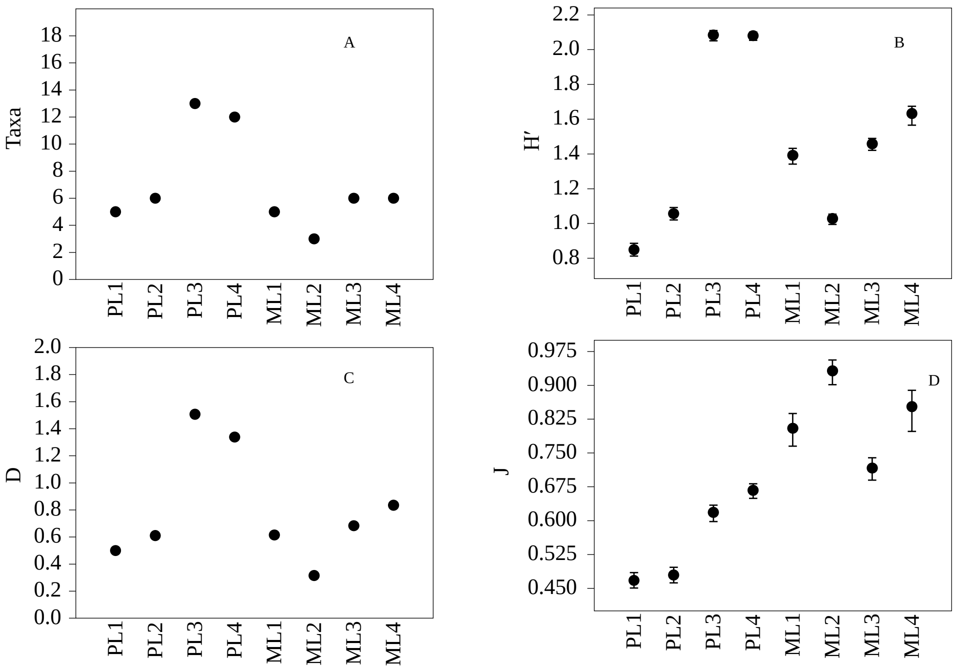

Figure 7. Variability of Polychaete diversity indices in the present study (A: Number of taxa, B: S-W index; C: species richness; D: Evenness index)

It can be summarized from this study that; ship-breaking activities had a greater impact on the macrobenthos community. Abundance, number of taxa, diversity index, and species richness were higher in the non-ship-breaking area than the ship-breaking area. Besides, the Polychaeta community and several pollution indicator taxa denoted that ship-breaking area was facing contamination which causes the differences with non-ship-breaking area. Therefore, we hypothesize that there might be some pollution like metal concentration, or petroleum hydrocarbon, or organic matter which was responsible for the decrease of macrobenthos in the ship-breaking area. Rainfall might have a positive influence on the reduction of detrimental impacts on the impacted site. However, further research is recommended to know the comprehensive impact of ship-breaking (organic and inorganic pollution) on macrobenthos in this area.

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