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Research Article

Diversity and assemblage pattern of finfish and shellfish along the Sitakunda coast, Bay of Bengal

S I Ara*[,a], M Nasiruddin[a], M M Sarker[a] & M A Azadi[b]

[a]Department of Zoology, University of Chittagong, Chattogram – 4331, Bangladesh
[b]International Islamic University Chittagong, Kumira, Chattogram – 4318, Bangladesh

*[E-mail: syedaismat@cu.ac.bd]

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Finfish and shellfish diversity at three sampling sites of the Sitakunda coast of the Bay of Bengal were studied monthly from March 2016 to February 2018, wherein 355181 fishery individuals were enumerated from 554 catch samples collected by 13 different types of gears. Out of a total of 168 fish species identified, 124 were finfish species (13 orders and 47 families), and 44 were shellfish species (2 orders and 8 families). The order Decapoda (65.17 %) occupied the highest position, followed by Perciformes (20.59 %), Scopeliformes (5.37 %), Clupeiformes (4.97 %), Siluriformes (1.35 %), Pleuronectiformes (1.18 %) and the remaining 9 orders contributed only 1.36 % of the total sampled population. *Oxyurichthys keiensis* is reported as a new record for Bangladesh. The highest numbers of individuals during pre-monsoon were recorded at Station II, and the lowest numbers of individuals from Station III during the post-monsoon season. Diversity indices showed no significant difference across years, but a significant differences were observed among stations. Stations I and II showed comparatively higher species abundance and diversity. According to the evenness index, the population of Station II was the most stable among the three stations. Analysis of Similarity (ANOSIM), Similarity Percentage Analysis (SIMPER), cluster analysis, and non-metric multidimensional scaling revealed clear differences in species populations across seasons.

[**Keywords**: Analysis of Similarity (ANOSIM), Bay of Bengal, Diversity index, Finfish, Shellfish, Sitakunda coast]

Introduction

Coastal and marine regions of Bangladesh are among the most diverse ecosystems on Earth, with high levels of biodiversity, increased production, and distinctive mangrove impacts[1]. The coastal waters of Bangladesh are home to diverse fishery resources, which comprise about 511 species of finfish and shrimp[2]. The fisheries sector is an important part of Bangladesh's economy, with the marine fisheries sector accounting for a large share. But sufficient scientific information on the fish species stock is lacking, which is very important for the potential exploitation of coastal and marine fisheries. As a result, overexploitation and underexploitation of fish stock occur inshore and offshore, respectively[1]. A gradual decline in catch per unit effort (CPUE) in the coastal fisheries of the Bay of Bengal has been observed, and several marine fish and shrimp stocks are on the verge of local extinction[3].

Sitakunda coast is an important region for Bangladesh’s coastal fisheries, situated in the southeastern coastal zone of the Bay of Bengal. It covers almost 20 km of uninterrupted coastline, where many local people depend on fishing for their livelihood. This region is very densely populated, and many industries, like ship-breaking yards and other manufacturing factories, have grown up along the coastline and adjacent areas, which eventually discharge waste products into the Bay of Bengal through small hilly streams and canals. As a result, the region is subjected to industrial pollution and overexploitation, which severely affect the fisheries diversity and the fisheries exploitation potential of the area. The coastline is covered by patches of mangrove forest, which serve as breeding grounds for many fish and shrimp species[1]. However, indiscriminate fishing using destructive fishing gears captures several immature stages of fish, leading to a decline in the natural stock of many fish species, which further gradually pushes the species towards local extinction[4].

A number of works have been done on coastal and estuarine fish diversity in Bangladesh[5-13], but very scanty information on the fishery diversity and fish stocks of the Sitakunda coast is found[14]. Information on the diversity and stocks of finfish and shellfish is very important for the proper exploitation and management of the coastal fisheries. Hence, to aid conservation and proper management of fisheries resources, this study focuses on the assessment of fish diversity in the Sitakunda coast of Bangladesh.

Materials and Methods

Study area

Three stations, namely Sitakunda (22°35′ N and 91°37′ E), Kumira (22°30′ N and 91°42′ E), and Bhatiary (22°25′ N, and 91°45′ E), along the Sitakunda coast were selected for present study (Fig. 1). Sitakunda (Station I), situated at the north of the other two stations, has very few industries on the mainland and almost with no ship breaking yards. Patches of mangrove forests (planted), although reduced, are still present on this coastline. Kumira (Station II), situated in the middle of the other two stations, has many industries on the mainland and a number of ship-breaking yards along the coast. Planted mangrove forests have almost vanished. Bhatiary (Station III), situated in the south of the other two stations, has many industries on the mainland as well as ship-breaking yards along the coastline. No planted mangrove forest exists in this area now.

Data collection

Data were collected from 20 km of coastline, starting from Sitakunda to Bhatiary. Fish samples from the full catch of a gear were collected directly from the fishermen at the three sampling stations. A total of ten types of fishing gears (two types of ESBNs, three types of gill nets, enclosure net, cast net, push net, long line, hand line), and three types of traps (funnel-mouthed cylinder trap, box trap, and crab trap) were used for collecting the fish samples. Full moon and new moon times was selected for sampling because the catch and fish abundance were relatively higher during these periods, according to local fishermen. Samples were then preserved in 8 % formaldehyde and kept in the laboratory of the Department of Zoology, University of Chittagong for further study.

Fish diversity

A standard literature was used for the identification and classification of finfishes[15-21] and shellfish[18,22-24]. Over the course of the two-year study period, a total

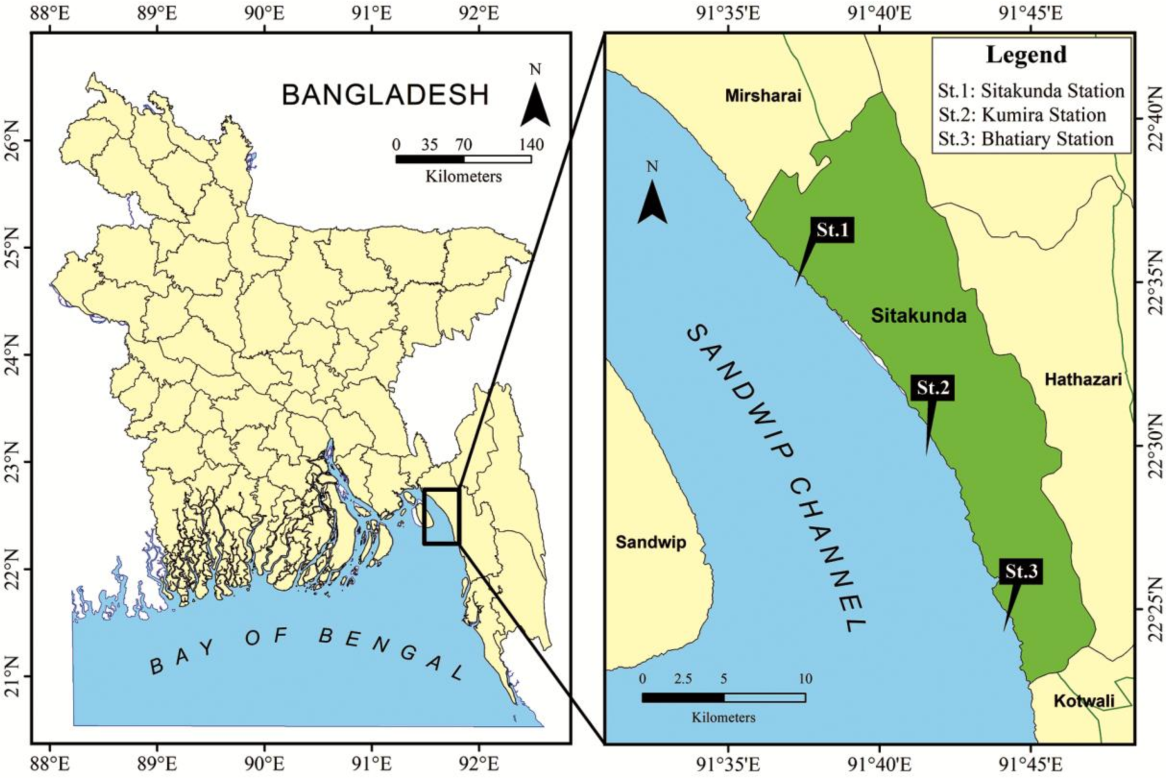

Fig. 1 — Study area located on the Sitakunda coast, Bangladesh. The inset (bottom right) shows the country map, the top right highlights the study location (red-marked), and the left displays a zoomed satellite view of the sampling stations (red, yellow, and green circles)

of 554 fish capture samples, comprising 355181 individual fish, were gathered monthly using 13 different types of fishing gear. Computer programs such as Microsoft Excel, Species Diversity and Richness 4 (SDR, version 4.1.2), the Statistical Package for the Social Sciences (SPSS), and the Community Analysis Package (CAP, version 5.0.0.465) were used to process and evaluate the collected data. Fish diversity was measured using a variety of diversity indices and species abundance.

Species abundance

A species comprising over 25 % of the total population is graded A+ and considered very common. Similarly, a species comprising over 5 % of the population is graded A, and considered common; species that has more than 1 % of the total population is graded A^- and considered less common; species that makes up over 0.5 % of the entire population is graded B^+ and considered to have a moderate presence; species having above 0.1 % of the total population is graded B and considered few; etc. Further, when a species accounts for more than 0.05 % of the entire population, it is graded B^- and is considered very few. A species comprising over 0.01 % of the entire population is graded C^+ and considered rare. A species comprising over 0.005 % of the overall population is graded C and considered very rare, and a species that makes up over 0.001 % of the overall population is graded D and considered extremely rare.

Diversity indices

Species richness, Simpson index of diversity[25], Shannon-Weiner diversity index and species evenness[26] were used as narrated below:

Species richness (S) = Total number of species in a given area

Simpson's index of diversity (D) Statistic, C *(or Y)* is given by:

$$\mathrm{C} = \sum_{i}^{\mathrm{SOBS}} Pi^2$$

Where, SOBS denotes the number of observations and

$$Pi^2 = \frac{Ni(Ni-1)}{NT(NT-1)}$$

It is typically approximated as follows:

$$Pi^2 = \left(\frac{Ni}{NT}\right)^2$$

Where, Ni represents the number of individuals in the ith species, while NT represents the total number of individuals in the sample.

The index is:

$$D = \frac{1}{C}$$

Shannon index or Shannon-Weiner index (H′)

$$\mathrm{H}' = -\sum_{i=1}^{S} (Pi\; lnPi)$$

Species evenness (E)

$$E = \frac{\mathrm{H}'}{ln\; S}$$

Where, S is the species richness and H' is the Shannon-Weiner index.

Species Diversity and Richness 4 (SDR, version: 4.1.2) was used to calculate diversity indices. Using the Statistical Package for the Social Sciences (SPSS 20), a two-way ANOVA was performed to ascertain the differences in biodiversity indices (Shannon–Wiener diversity, Simpson’s index, species richness, and species evenness) across the seasons and stations.

Diversity analysis for spatial and temporal assemblages

ANOSIM (Analysis of Similarity), Similarity Percentage Analysis (SIMPER), cluster analysis, and Non-metric Multidimensional Scaling (NMDS) have all been used to assess fish diversity and assemblage patterns based on species abundance and other diversity indices.

ANOSIM (Analysis of Similarity)

Clarke[27] suggested the following statistic to gauge the group differences based on the Bray-Curtis similarity method:

$$R = \frac{rB - rw}{n(n-1)/4}$$

Where, n is the total number of samples and rB and rw are the means of the ranked similarity between and within groups, respectively. The Community Analysis Package (CAP, version: 5.0.0.465) was used to determine ANOSIM.

Similarity Percentage analysis (SIMPER)

The Bray-Curtis similarity measure served as the foundation for this investigation[28]. The contributing and discriminating species for each season were identified using SIMPER. The Community Analysis Package (CAP, version: 5.0.0.465) was used to determine the similarity percentage.

Cluster analysis

To create a dendrogram, the hierarchical clustering[29] was computed. Using the Bray–Curtis similarity index, the dendrogram displayed the similarities and differences between species groups in each season with respect to abundance. The Community Analysis Package (CAP, version: 5.0.0.465, PISCES Conservation Ltd.) was used to create the dendrogram of the seasons and stations.

Non-Metric Multidimensional Scaling (nMDS)

To illustrate and identify the similarities and differences in species assemblages across seasons, Non-Metric Multidimensional Scaling (nMDS), a mostly two-dimensional diagram, was employed. The species makeup of each season was used to create a two-dimensional nMDS.

Results

A total of 355181 fish individuals were counted during the study period from 554 catch samples that were gathered from the three sampling sites along the Sitakunda coast using ten different types of fishing nets and three different types of fishing traps.

Species abundance, composition, and distribution

A total of 168 fish species (124 finfish and 44 shellfish species) were recorded from the catches of 13 different gears during the two-year study period. In the first and second years, 161 species (including 118 finfish and 43 shellfish) and 166 species (including 122 finfish and 44 shellfish), respectively, were discovered. The distribution of species within the population varied widely, ranging from 0.001 % to 40.81%. The most prevalent species across all stations were *Acetes* sp. (48.81 %), *Odontamblyopus rubicundus* (9.72 %), *Harpodon nehereus* (5.37 %), *Parapenaeopsis sculptilis* (3.9 3%), and *Leptocarpus potamiscus* (2.87 %). The populations of *Laubuka laubuca*, *Elops machnata*, *Oxyurichthys microlepis*, *Eleotris lutea*, and *Awaous guamensis* had the lowest percentages (0.001 %) of individuals (Table S1).

In the first year (2016 – 2017), of the 161 species, one species (*Acetes* sp.) was listed as very common (A+), two (*O. rubicundus* and *H. nehereus*) as common (A), ten as less common (A^{-}), eighteen species as moderate (B+), forty-seven as few (B), eighteen as very few (B^{-}), thirty-five as rare (C+), sixteen listed as very rare (C), and fourteen as extremely rare (D) (Table S1). Similarly, of the 166 species identified in 2017 – 2018, one species (*Acetes* sp.) was classified as very common (A+), two (*O. srubicundus* and *H. nehereus*) as common (A), eleven as less common (A^{-}), sixteen as moderate (B+), fifty-two as few (B), sixteen as very few (B^{-}), thirty-six as rare (C+), twenty-two as very rare (C), and ten as extremely rare (D) (Table S1).

The total fish species belonged to 13 orders of finfish and 2 orders of shellfish. The order Decapoda (65.17 %) occupied the highest position in the population, followed by Perciformes (20.59 %), Scopeliformes (5.37 %), Clupeiformes (4.97 %), Siluriformes (1.35 %), Pleuronectiformes (1.18 %) and the remaining 9 orders contributed only 1.36 % of the total population (Fig. 2).

Diversity indices

Species richness (S)

The species richness (S) of the total studied fishes during the two years in three stations of the Sitakunda coast was 168. Among these 168 species, 161 and 166 species were found in 2016 – 2017 and 2017 – 2018, respectively (Table 1). In the 1st year, the highest number of fish species was found in Station 1 (161), followed by Station 2 (151), and Station 3 (138). In the 2nd year, the highest number of fish species was also found in Station 1 (166), followed by Station 2 (156) and Station 3 (147) (Table 1).

Simpson diversity index (D)

The Simpson diversity index (D) for total individuals was 5.408 and 5.451 in the 1st and 2nd

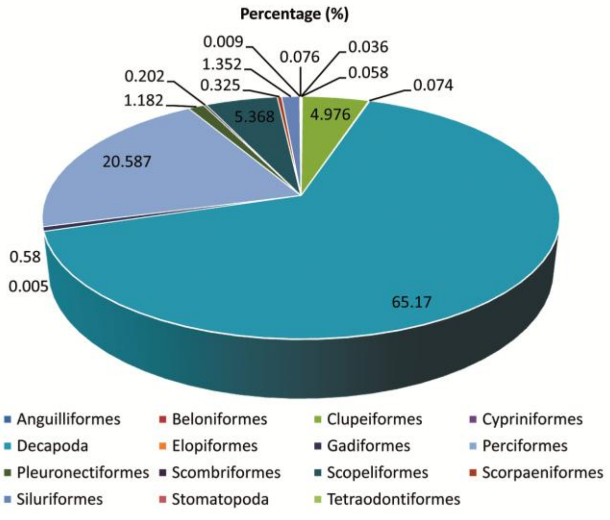

Fig. 2 — Composition of orders of the finfish and shellfish species in the Sitakunda coastal area

years, respectively, and the highest value was found in the 2nd year from Station 1 (5.746) (Table 1). The highest values of the Simpson diversity index were 5.632 in Station 2, 5.607 in Station 1, and 4.987 in Station 3 during the 1st year, and 5.746 in Station 1, 5.587 in Station 2, and 5.451 in Station 3 during the 2nd year of study period (Table 1). ANOVA showed no significant difference between the populations of the two years ($P = 0.85 > 0.05$), but did show a significant difference among the populations of three stations ($P = 0.002 < 0.05$). The Simpson index indicated that species composition in all stations was diversified, and no station had infinite diversity.

Shannon-Wiener diversity index (H')

In the first and second years, the Shannon-Wiener diversity indices (H') were 2.945 and 2.935, respectively (Table 1). Stations 1 and 2 had the highest Shannon-Wiener diversity index values in the first year, at 3.011 and 2.991, respectively, while Station 3 had 2.813. Station 1 (3.016) had the highest Shannon-Wiener diversity index value in the second year, followed by Stations 2 (2.950) and 3 (2.818) (Table 1). The ANOVA revealed a significant difference between the three stations' populations ($P = 0.0027 < 0.05$), but no significant difference between the two-year populations ($P = 0.9 > 0.05$). According to the Shannon-Wiener diversity measure, every species was included in a randomly selected sample.

Species evenness (E)

In the first and second years, the evenness (E) values for the total number of individuals were 0.034 and 0.033, respectively (Table 1). In the first year, Station 2 had the highest evenness value (0.037), followed by Station 3 (0.036) and Station 1 (0.035); whereas, in the second year, Station 2 had the maximum evenness value (0.036), followed by Station 1 (0.035) and Station 3 (0.034) (Table 1). ANOVA showed no significant difference between the populations of two years ($P = 0.3 > 0.05$) and among the populations of three stations ($P = 0.2 > 0.05$). According to the evenness index, the fish population at Station 2 was more evenly distributed than that of the other two stations. The ecosystem of Sitakunda coast (Station 1) lacked absolute stability, whereas the ecosystem of Station 2 was more stable than those of the other two stations.

Analysis of Similarity (ANOSIM)

In the first year, analysis of similarity (ANOSIM) revealed significant differences in species composition among seasons, except between the pre-monsoon and winter seasons ($R = 0.172$, $P = 0.053$). Notable dissimilarities were observed between the monsoon and post-monsoon, monsoon and pre-monsoon, monsoon and winter, post-monsoon and pre-monsoon, and post-monsoon and winter seasons (Table 2).

Similarly, in the second year, ANOSIM indicated significant seasonal variation in species assemblages ($R = 0.690$, $P = 0.001$). Pair-wise comparisons showed clear dissimilarities between monsoon and post-monsoon, monsoon and pre-monsoon, monsoon and winter, post-monsoon and pre-monsoon, post-monsoon and winter, and pre-monsoon and winter (Table 2).

Throughout both years of the study, ANOSIM detected no significant differences in fish community structure across the sampling stations.

Similarity Percentages (SIMPER) Analysis

According to the first year's Similarity Percentages (SIMPER) analysis, *Odontamblyopus rubicundus* (31.51 %) was the species that contributed the most during the monsoon season, followed by *Leptocarpus potamiscus* (6.71 %), and *Harpodon nehereus* (6.51 %). During the post-monsoon season, *Leptocarpus potamiscus* (9.78 %) contributed the most, followed by *Exopalaemon styliferus* (6.22 %), and

Table 1 — Species richness, Simpson diversity index, Shannon-Wiener diversity index, and evenness in three stations of the Sitakunda coast

Diversity indices	**Year**	**Station 1**	**Station 2**	**Station 3**	**Average/Total**
Species richness	2016-17	161	151	138	161
	2017-18	166	156	147	166
Simpson diversity index	2016-17	5.607	5.632	4.987	5.408
	2017-18	5.746	5.587	5.019	5.451
Shannon- Wiener diversity index	2016-17	3.011	2.991	2.813	2.946
	2017-18	3.016	2.95	2.818	2.935
Evenness	2016-17	0.035	0.037	0.036	0.034
	2017-18	0.035	0.036	0.034	0.033

Table 2 — Result of one-way ANOSIM (*R* value and *P* value)

GROUPS		**2016-17**		**2017-18**	
		R	***P***	***R***	***P***
Seasons	Monsoon Vs. Post-monsoon	0.685	0.001	0.393	0.008
	Monsoon Vs. Pre-monsoon	1	0.001	1	0.001
	Monsoon Vs. Winter	1	0.001	1	0.001
	Post-monsoon Vs. Pre-monsoon	1	0.001	0.991	0.001
	Post-monsoon Vs. Winter	0.990	0.001	0.977	0.001
	Pre-monsoon Vs. Winter	0.172	0.053	0.230	0.008
Stations	Station 1 vs. Station 2	-0.076	0.992	0.999	-0.081
	Station 1 vs. Station 3	-0.073	0.988	0.989	-0.069
	Station 2 vs. Station 3	-0.069	0.983	0.991	-0.074

Parapenaeopsis sculptilis (5.30 %). During the pre-monsoon season, *Acetes* sp. (60.81 %) contributed the most, followed by *H. nehereus* (6.64 %), and *P. sculptilis* (4.73%); and during the winter, *Acetes* sp. (56.37 %) contributed the most, followed by *H. nehereus* (4.99 %), and *P. sculptilis* (4.22 %). The winter season had the highest average similarity percentage (84.15 %), followed by the pre-monsoon season (84.14 %), the monsoon season (72.77 %), and the post-monsoon season (58.33 %).

In the 2nd year, the SIMPER analysis showed that *O. rubicundus* (30.95 %) was the highest contributory species followed by *L. potamiscus* (6.57 %), and *H. nehereus* (5.78 %) in the monsoon season; *L. potamiscus* (11.44 %) followed by *O. rubicundus* (9.40 %), and *P. sculptilis* (8.25 %) in the post-monsoon season; *Acetes* sp. (60.43 %) followed by *H. nehereus* (5.41 %), and *P. sculptilis* (3.59 %) in the pre monsoon season; and *Acetes* sp. (56.45 %) followed by *H. nehereus* (6.47 %), and *P. sculptilis* (3.52 %) in the winter season. The highest percentage of average similarity was observed in the winter (87.43 %), followed by pre-monsoon (82.17 %), monsoon (73.94 %), and post-monsoon (52.54 %) seasons.

In the first year (2016–2017), SIMPER analysis revealed differences in species assemblages between two seasons (Table 3). Highest average dissimilarity was found between post-monsoon and pre-monsoon seasons (77.94 %), and the major discriminating species were *Acetes* sp. (62.01 %), *H. nehereus* (5.96%) and *P. sculptilis* (3.41%). Average dissimilarities were also found between post monsoon and winter seasons (74.72 %) and the major discriminating species were *Acetes* sp. (57.60 %), *H. nehereus* (6.08 %) and *P. sculptilis* (3.23 %); during monsoon and pre monsoon seasons (65.59 %), the major discriminating species were *Acetes* sp. (59.95 %), *O. rubicundus* (15.05 %), and *H. nehereus* (3.11 %); during monsoon and winter seasons (62.26 %), the major discriminating species were *Acetes* sp. (54.86 %), *O. rubicundus* (17.67 %), and *H. nehereus* (3.84 %); and between monsoon and post-monsoon seasons (57.69 %) where the major discriminating species were *O. rubicundus* (35.92 %), *H. nehereus* (6.34 %), and *P. sculptilis* (4.65 %). The lowest average dissimilarity was found between the pre-monsoon and winter seasons (19.60 %), and the major discriminating species were *Acetes* sp. (48.87 %), *H. nehereus* (6.56 %), and *L. potamiscus* (2.82 %). Additionally, SIMPER analysis revealed that the species assemblages in the second year (2017 – 2018) differed between the two seasons (Table 3). The highest average dissimilarity was found between post-monsoon and pre-monsoon seasons (78.85%) and the major discriminating species were *Acetes* sp. (58.91 %), *O. rubicundus* (9.81 %) and *H. nehereus* (4.93 %); between post-monsoon and winter seasons (76.39 %), the major discriminating species were *Acetes* sp. (53.36 %), *O. rubicundus* (11.29 %) and *H. nehereus* (6.18 %); between monsoon and pre-monsoon seasons (64.897 %), the major discriminating species were *Acetes* sp. (62.00 %), *O. rubicundus* (13.61 %), and *H. nehereus* (2.60 %); between monsoon and winter seasons (61.47 %), the major discriminating species were *Acetes* sp. (55.96 %), *O. rubicundus* (16.47 %), and *H. nehereus* (3.27 %); between monsoon and post-monsoon seasons (54.43 %), the major discriminating species were *O. rubicundus* (39.36 %), *H. nehereus* (6.75 %) and *L. potamiscus* (2.56 %). The lowest average dissimilarity was found between pre-monsoon and winter seasons (18.9771 %), and the major discriminating species were *Acetes* sp. (47.90 %), *H. nehereus* (4.33 %), and *P. sculptilis* (3.89 %).

Cluster analysis

Three main clusters were found using cluster analysis in the first and second years of investigation, respectively. Regarding the seasonal catch

Table 3 — Result of SIMPER analysis showing average dissimilarity between seasons and the contribution of the major discriminating species among various seasons

GROUPS	**Average dissimilarity (%)**		**Year**	**Major discriminating species**	**Contribution (%)**
	2016-17	**2017-18**			
Monsoon *vs.* Post-monsoon	57.6893	54.4322	2016-17	*Odontamblyopus rubicundus*	35.9158
				Harpodon nehereus	6.33511
				Parapenaeopsis sculptilis	4.65164
			2017-18	*Odontamblyopus rubicundus*	39.3637
				Harpodon nehereus	6.7514
				Leptocarpus potamiscus	2.56447
Monsoon *vs.* Pre-monsoon	65.5963	64.8972	2016-17	*Acetes* sp.	59.9483
				Odontamblyopus rubicundus	15.0526
				Harpodon nehereus	3.10768
			2017-18	*Acetes* sp.	62.0022
				Odontamblyopus rubicundus	13.609
				Harpodon nehereus	2.60221
Monsoon *vs.* Winter	62.2597	61.4686	2016-17	*Acetes* sp.	54.8633
				Odontamblyopus rubicundus	17.6677
				Harpodon nehereus	3.83719
			2017-18	*Acetes* sp.	55.9578
				Odontamblyopus rubicundus	16.4679
				Harpodon nehereus	3.26708
Post-monsoon *vs.* Pre-monsoon	77.941	78.8503	2016-17	*Acetes* sp.	62.0073
				Harpodon nehereus	5.95563
				Parapenaeopsis sculptilis	3.41098
			2017-18	*Acetes* sp.	58.9141
				Odontamblyopus rubicundus	9.80713
				Harpodon nehereus	4.92899
Post monsoon *vs.* Winter	74.7248	76.3914	2016-17	*Acetes* sp.	57.5964
				Harpodon nehereus	6.07629
				Parapenaeopsis sculptilis	3.23129
			2017-18	*Acetes* sp.	53.3579
				Odontamblyopus rubicundus	11.2874
				Harpodon nehereus	6.18219
Pre monsoon *vs.* Winter	19.6017	18.9771	2016-17	*Acetes* sp.	48.8706
				Harpodon nehereus	6.56033
				Leptocarpus potamiscus	2.81846
			2017-18	*Acetes* sp.	47.9036
				Harpodon nehereus	4.32505
				Parapenaeopsis sculptilis	3.892

composition, the dendrogram derived from abundance data collected over the two-year study period revealed three distinct assemblages (Figs. 3 and 4). The second and third assemblages had monsoon and post-monsoon seasonal catch compositions in both years, while the first assemblage featured pre-monsoon with winter seasonal catch compositions.

Non-Metric Multidimensional Scaling (nMDS)

Non-metric multidimensional scaling (nMDS) revealed three distinct groups in the seasonal catch composition of species (Figs. 5 and 6) for both the years. The results of nMDS were supported by the ANOSIM and Cluster analysis (Figs. 3 and 4). It showed a distinction between monsoon and post-monsoon. It also showed dissimilarity between the monsoon and winter, monsoon and pre-monsoon, post-monsoon and pre-monsoon, and post-monsoon and winter seasons, but not between pre-monsoon and winter seasons. It refers to the significant difference among the seasons.

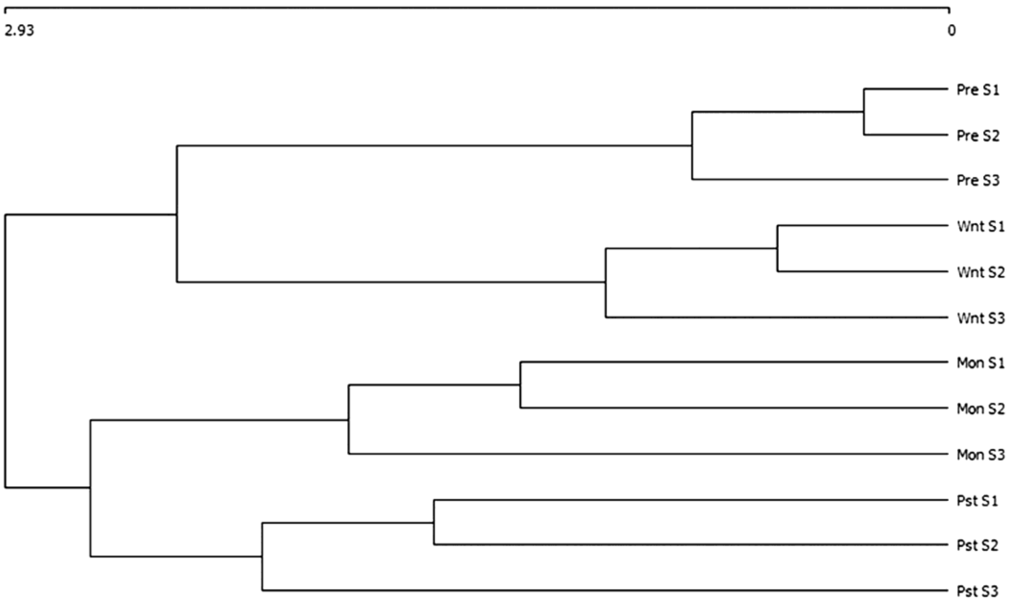

Fig. 3 — Dendrogram showing the cluster of finfish and shellfish assemblages in the separate stations and seasons (Pre-monsoon = Pre; Monsoon = Mon; Post-Monsoon = Pst; Winter = Wnt) during 2016 – 17

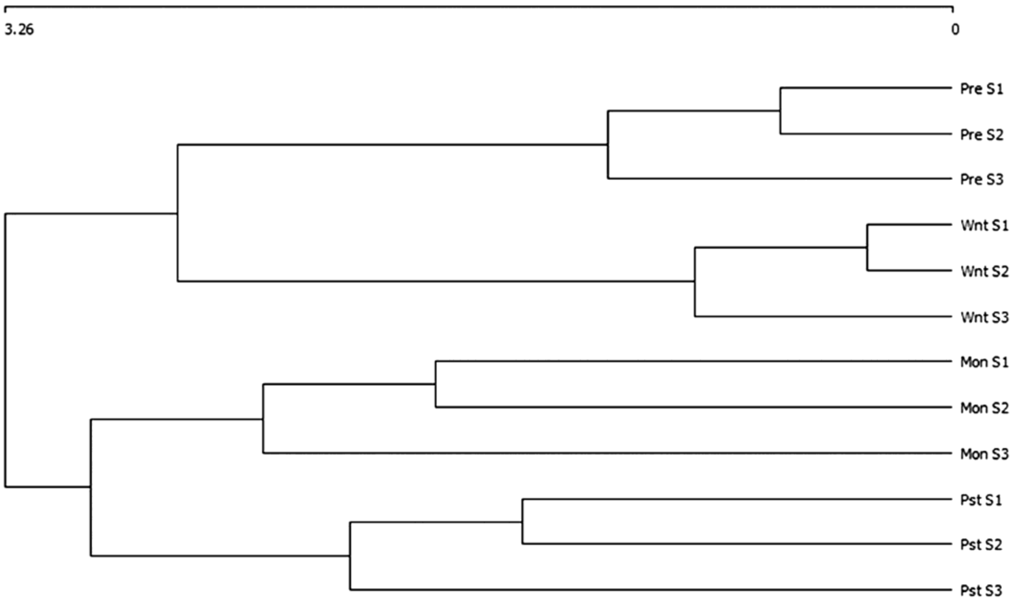

Fig. 4 — Dendrogram showing the cluster of finfish and shellfish assemblages in the separate stations and seasons (Pre-monsoon = Pre; Monsoon = Mon; Post-Monsoon = Pst; Winter = Wnt) during 2017 – 18

Discussion

The study aimed to explore the faunal diversity and distributional pattern of fishery species in the Sitakunda coast of Bangladesh. Over the two-year study period, 168 fishery species were identified using the 13 fishing gears: 124 finfish species belonging to 48 families and 13 orders, and 45 shellfish species belonging to 8 families and 2 orders. Among the shellfish, 35 species were shrimps and prawns (5 families), 9 crabs (3 families), and 1 Stomopod (1 family). Shellfish belonged to two orders, Decapoda (shrimps and crabs) and Stomopoda. Among the finfish species, *Oxyurichthys keiensis*[21], was found as a new record for Bangladesh. The present report is much higher than that of the previous records of the same and adjacent coasts, such as 28 species of finfish and shellfish from the Sitakunda coast[14], and 68 species of fish from the Chittagong coast[6]. But the present report is

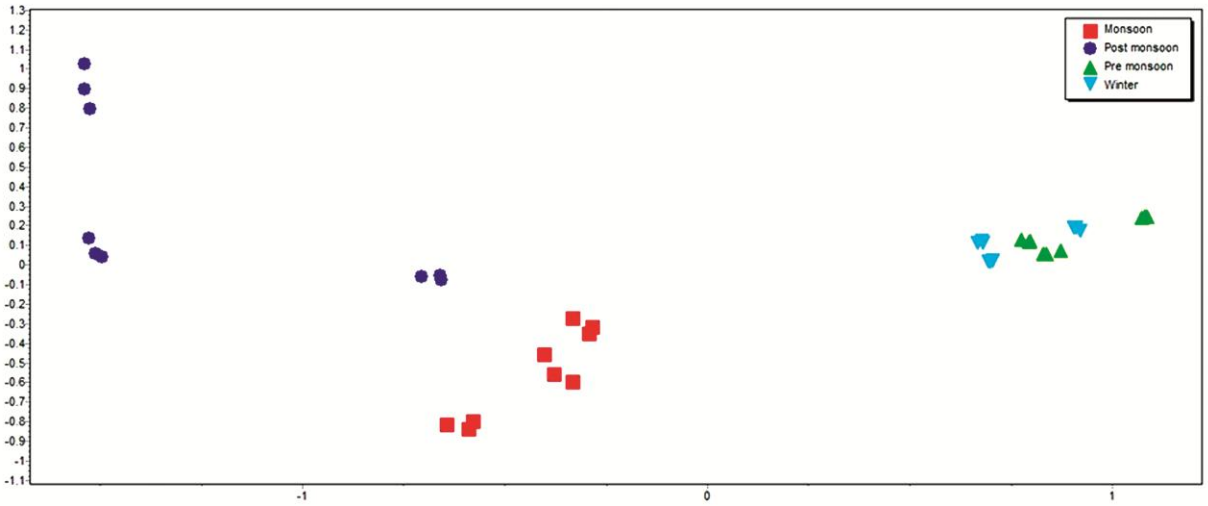

Fig. 5 — Non-Metric Multidimensional Scaling (nMDS) showing groups for the seasonal catch composition of species during 2016 – 17

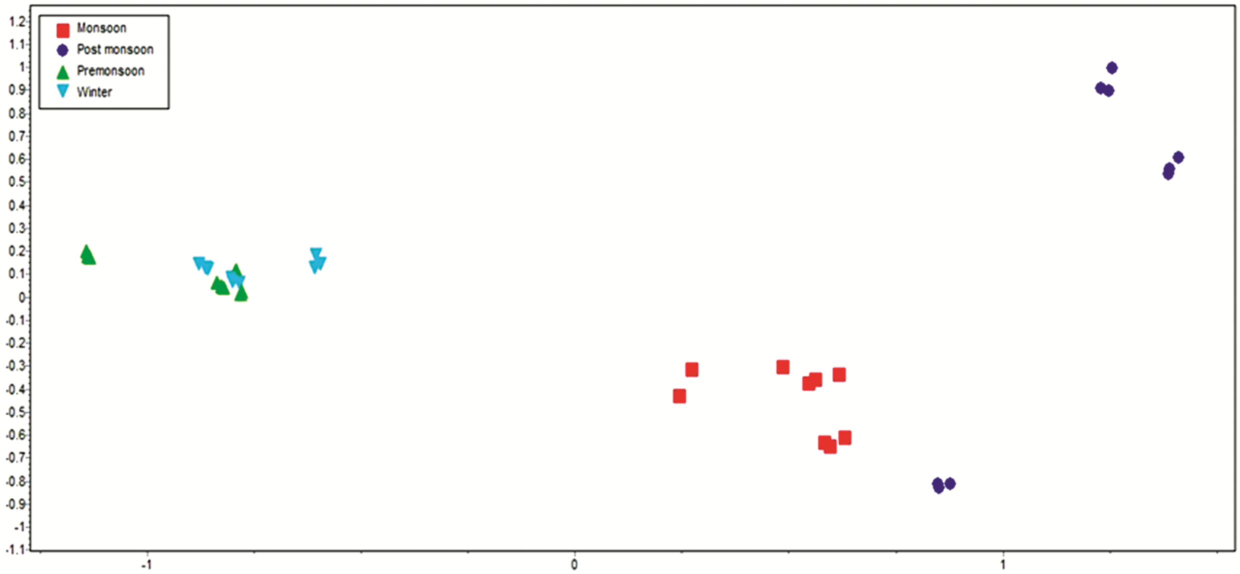

Fig. 6 — Non-metric Multidimensional Scaling (nMDS) showing groups for the seasonal catch composition of species during 2017 – 18

more or less similar to some previous coastal records of Bangladesh like Quddus & Shafi[15] who reported 139 species from marine and brackish water of Bangladesh, Ahmed[30] reported 141 species of brackish water fish from coastal Bangladesh, Hossain *et al*.[31] reported 167 fish species from Naaf river estuary, Islam *et al*.[32] who reported 185 finfish species from the coastal waters of Bangladesh, and Thirty-five species of fish and 10 shrimp species was reported by Rashed-Un-Nabi *et al.*[11] from Bakkhali river estuary.

The most contributing species in the present study was *Acetes* sp., a shrimp species, which varied in proportions across the three stations along the coast of Sitakunda. Among the finfish, the highest contributing species was *Odontamblyopus rubicundus*, followed by *Harpodon nehereus*. Zafar & Alam[33] also reported a species of *Acetes* (*Acetes erythraeus*) as the highest contributing species from the Kutubdia channel, Bangladesh. Rashed-Un-Nabi *et al.*[11] found *Metapenaeus lysianassa* as a dominant species from the Bakkhali river estuary. Of the 168 species recorded, the 5 species contributed 62.69 % of the total abundance, and the remaining 163 species accounted for only 37.3 %. The leading contributory orders were Decapoda (65.17 %) and Perciformes (20.58 %), but among the finfish species, the leading orders were Perciformes and Cluepiformes. In the population, the maximum contributory order was Decapoda (65.17 %), while the minimum was Elopiformes (0.007 %). The analysis of similarity (ANOSIM) and similarity percentage analysis (SIMPER) showed clear dissimilarity between the seasons in both years, but no significant difference in fish group structures was found among the stations (Tables 2 & 3). This might be due to the uniformity of the coastal environment, as continuous tidal activity mixes up the water, and also, the distance between the three sampling stations might not be long enough to make a significant difference. While Barletta *et al.*[34] observed substantial differences in the number of species and overall mean density among locations and seasons in the Paranaguaa estuary of Brazil, the seasonal difference in the current study is consistent with the findings of Hossain *et al.*[13] from the Meghna River Estuary. Whitefield[35] proposed that seasonality, which causes variations in hydrobiological and climatic characteristics, is the primary factor influencing similarity and dissimilarity.

Cluster analysis revealed three separate groups based on the seasonal composition of the finfish and shellfish assemblages in the current study, both spatially and temporally. While the second and third assemblages had monsoon and post-monsoon seasonal catch compositions in both years, the first assemblage featured pre-monsoon with winter seasonal catch compositions. Rashed-Un-Nabi *et al.*[11] and Hossain *et al.*[13] identified two major groups from cluster analysis of the Bakkhali estuary and the Meghna River estuary, respectively. The Shannon-Weiner diversity index reflects both the number of species and the evenness of a community's population; an increase in the index indicates high diversity and evenness. In the present study, H′ values were found to be higher in the Sitakunda station (3.011 and 3.016), followed by Kumira station (2.991 and 2.95), and Bhatiary station (2.813 and 2.818), in 2016 and 2017, respectively. According to Acharjee & Barat[36], the H′ value range of 0–5 is frequently used to classify the water quality in any ecosystem, since values < 3 indicate polluted water and values > 3 indicate clear water with a good diversity of aquatic life. The H′ value of fish, according to Mishra *et al.*[37], ranged from 4 to 5 for very good quality, 3 to 4 for good quality, 2 to 3 for moderate quality, 1 to 2 for bad quality, and less than 1 for very poor water quality.

Hence, the H′ values of the present study clearly indicated that the water quality at Sitakunda station was very good, and that at the other two stations (Kumira and Bhatiary) was moderate. This might be due to the presence of industries and ship-breaking yards in those two stations, although the water quality in those two stations did not deteriorate much, as regular tidal activities might have removed much of the pollutants by diluting the concentration and hence providing less polluted water for the survival of fish and other aquatic animals.

Conclusion

Sitakunda coast is recognised as one of the most heavily exploited coastal areas in Bangladesh. Fisheries in this region not only suffer from destructive, non-selective multi-gears but also face heavy pollution from various industries and agricultural and domestic sources. Hence, it is crucial that laws and regulations governing the overexploitation and use of damaging fishing gear be strictly enforced. To prevent the shoreline from being drained of untreated wastewater from various enterprises, ship breaking yards, and other sources, immediate action is necessary. In view of these, extensive research on the biological and ecological aspects of fish populations along this coast is necessary.

Supplementary Data

Supplementary data associated with this article is available in the electronic form at https://nopr.niscpr.res.in/jinfo/ijms/IJMS_54(04)195-206_SupplData.pdf

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Conflict of Interest

The authors disclose that none of their known financial interests or personal connections would have influenced the work reported in this paper.

Author Contributions

SIA: Conceptualisation of the study, formal analysis, investigation, resources, and writing original draft. MAA & MN: Validation of the methodology, work supervision, reviewing and editing of the original draft. MMS: Formal analysis and data visualisation.

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