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ORIGINAL RESEARCH ARTICLE

Study of Seaweed Diversity and Water Physico-chemical Properties of Saint Martin's Island, Bangladesh

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St. Martin's Island is one of the unreached areas for the field of ecology, phycology and biodiversity research in global perspective. This study explored the present status of avaiable seaweeds and water physico-chemical properties through three locations (ST.1, ST.2 and ST.3) of the island. A total of 51 seaweed species were listed under 3 major groups, where Rhodophyceae possessed 41% species, following Phaeophyceae (31%) and Chlorophyceae (28%). The southern part (ST.3) consisted highest number of species (37%) and showed comparatively rich diversity according to three diversity indices (Shannon Weiner index, Simpson Index and Margalef index). The overall temperature found almost homogeneous in winter (24.68 °C) and pre-monsoon (29.05 °C). The lowest pH was recorded in northwestern location (ST.1) during high tide of winter (pH 8.34±0.24). The water was comparatively less saline in ST.2, and higher dissolved oxygen produced at ST.3 (7.05 to 7.58 mg/L). There were found significant relations among the physico-chemical properties and the seaweed groups in the island.

Keywords: Macroalgae, Correlation studies, Dissolved oxygen, Water temperature, Ecosystem.

The St. Martin's Island is recognized as the richest biodiversity hotspot and popular tourist location in Bangladesh (1). The surface area of the island is about 8 km^2 and it has some other small islands connected but separated at high tide from the main island. It looks almost like a flat and dumb-bell shaped land region, and located approximately 9 km far away from the southern mainland of Bangladesh (2). As other islands of the world, its coastal ecosystem is also blessed with many natural resources viz., seaweeds, plants, animals, corals and many other living and non living organisms (3,4).

Seaweeds are marine macroalgae and grow normally on rocks and other hard substrata of intertidal and subtidal zone. They have been used for foods, medicines, chemicals and other purposes by many nations from ancient to modern time (5-7). Apart from these, seaweeds support a wide range of biotic organisms to enrich the surrounding biodiversity in a coastal ecosystem. In the world, almost 8,000 species of seaweeds were reported till now; where the total number of seaweeds, their diversity as well as distribution in the island, even in the whole coastlines of Bangladesh is hardly available (8,9). Despite several authentic reports are available on seaweeds of the island, most of them were based species identification and some cases with species distribution (10,11). Measuring diversity of species is a very essential ecological tool to understand the conditions of any organisms in a particular area, region or ecosystem. However, in aquatic ecosystem, understanding the diversity is a complicated issue. Hence, ecologists apply many methods, different diversity indices, to measure diversity nowadays (12-14). Thus, there is a need arise to explore the diversity of seaweed species from the island (15).

Assessing water quality or health of an ecosystem, it is a prime concern to measure the physical and chemical factors in a water bodies. Moreover, these factors can influence the growth of aquatic photosynthetic organisms, and they support other life forms in many ways in an aquatic environment directly or indirectly (16-18). As important water physico-chemical factors, temperature, pH, salinity and dissolved oxygen are considered as essential for lives in an aquatic environment (19,20). For example, temperature and salinity has direct impacts on growth, community composition, development and distribution of aquatic organisms, while pH is a good indicator to assess the ocean acidification. Moreover, dissolved oxygen, another important water physico-chemical factor, is mandatory for the respiration of all aquatic life forms. These factors somewhere correlated with each other and also correlated with the algae of the concerning ecosystem (21). Thus it is very crucial to monitor these factors in a regular basis to evaluate the health of any ecosystem.

Therefore, this study aimed to evaluate the current ecosystem health of the island by assessing the seaweeds diversity and water physico-chemical properties. Moreover, the study also measured the possible relations within the key physico-chemical factors and available seaweeds in the Saint Martin's Island.

MATERIALS AND METHODS

Study Area

Geographical position of the Saint Martin's Island is located in 20°34´ to 20°39´N latitude, and 92°18´ to 92°21´E longitude. It is positioned from almost 9 km south from Cox's Bazar-Teknaf peninsular tip of Bangladesh, and almost 8 km west from Myanmar coast in the Bay of Bengal. Samplings were carried out through three stations namely, ST.1 (northwestern part), ST.2 (middle of the island) and ST.3 (southern part). Details of the study area were presented in Fig.1.

Seaweed Study

Seaweed samplings were carried out between December 2019 and March 2020. The quantitative measurements were conducted by line transect and quadrat methods (22). The studied areas were done by an underwater camera capturing photos (50 x 50 cm) as photoquadrats positioned at approximately 1 m above the seafloor assisted by a PVC stick from an engine boat through each line transect and photos were taken at an interval of 1 m to record seaweeds. To maintain accuracy, physical samplings were also conducted during low tide and up to 100 m deep through the several locations by a professional scuba diver and a volunteer. The recorded photos were analyzed using Excel extensions software. The seaweeds were identified, counted and listed with the help of authentic literature (3,10,11,23,24). Moreover, the species abundance as well as species richness and evenness of the counted seaweed taxa were calculated using PAST computer program, and these were done by different ecological indices, Shannon index, Simpson index and Margalef index for example.

Physico-chemical Properties Study

Water physico-chemical properties were measured in winter (November to January) and pre-monsoon season (March to May) of the year 2019 and 2020 during high tide and low tide time. Samples were collected monthly from the three stations by a sterilized plastic bottle. The measurement procedures were completed immediately after each sampling by several portable digital meters.

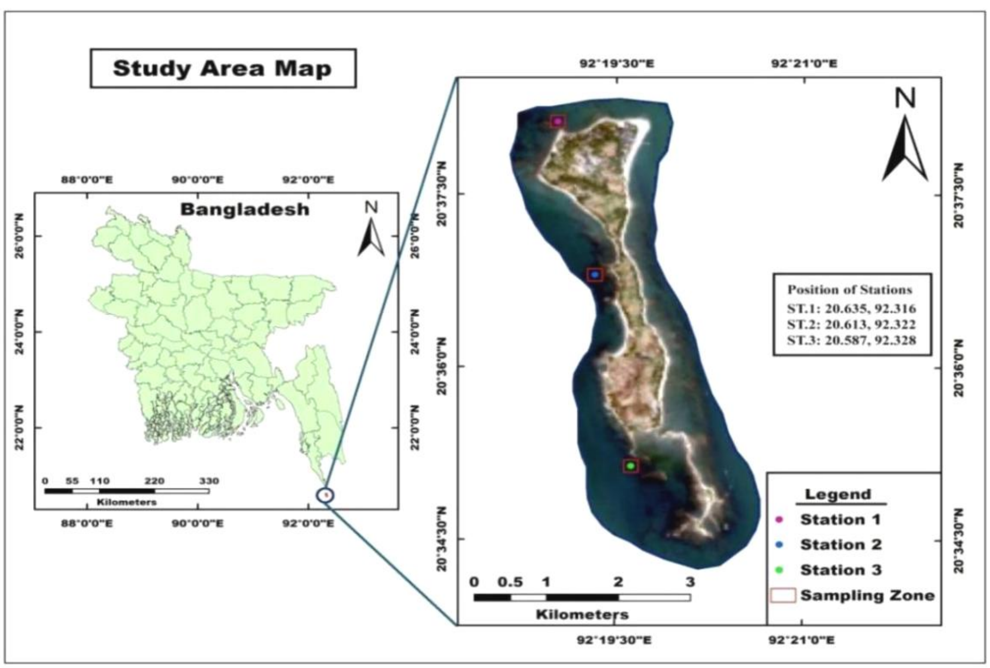

Fig.1. Location map of St. Martin's Island (SMI) with all sampling stations.

For example, temperature was measured by multi-stem thermometer (Dt-8811, Mextech, India, 0.1º C accuracy); pH was determined by glass electrode pH meter (pH-201, Lutron, Taiwan).
Total dissolved solids (TDS) and electrical conductivity (EC) were measured by hand held digital meters (TDS meter: HI98319, Hanna, USA, and EC meter:Atago hand refractometer, Japan).Furthermore, dissolved oxygen was calculated by digital DO meter (DO30, Clean Instruments, China).

Data Analysis

All data were processed in MS Excel 10 version. LSD between the calculated results of the physico-chemical properties were done by the Genstat software program ($P \leq 0.05$). For diversity measurement, we used free PAST software. JMP program was used to study correlations among the parameters.

RESULTS

Seaweed Diversity

This study reported a list of 51 seaweeds species from 34 genera under three major groups, namely Chlorophyceae, Phaeophyceae and Rhodophyceae (Table 1). According to Fig.2, most of the taxa were listed under Rhodophyceae (possessed 41% taxa), following Phaeophyceae (31%) and Chlorophyceae (28%). Moreover, 37% of the listed seaweeds taxa were found in ST.3, following 34% in ST.1 and 29% in ST.2 (Fig.3). The taxa *Enteromorpha prolifera*, *Sargassum wightii*, *Ceramium brevizonatum*, *Corallina officinalis*, *Gelidium spinosum*, *Halymenia floresia*, *Halymenia floridana* and *Porphyra nereocystis* found only at ST.1, while *Avrainvillea amadelpha*, *Padina pavonica*, *Spatoglossum variabile*, *Dasya corymbifera* and *Gracilaria spinuligera* were recorded from ST.2. The species *Caulerpa chemnitzia*, *Codium geppei*, *Dictyota atomaria*, *Dictyopteris australis*, *Hydroclathrus clathratus*, *Padina tenuis*, *Sargassum coriifolium*, *Sargassum olygocystum*, *Asparagopsis taxiformis*, *Callophyllis variegata*, *Chrysymenia agardhii*, *Dasya pedicellata*, *Liagora ceranoides* and *Vanvoorstia coccinea* were found only at the ST.3 area. Furthermore, the 9 taxa *Caulerpa racemosa*, *Caulerpa taxifolia*, *Halimeda discoidea*, *Halimeda opuntia*, *Ulva lactuca*, *Sargassum swartzii*, *Hypnea boergesenii*, *Hypnea musciformis* and *Jania ungulata* were commonly found all the three studied stations. In total 6 taxa, as a single genus, were counted under *Sargassum* followed by *Caulerpa* (5 taxa) and *Padina* (3 taxa) from the island during the studied time and locations. Among the three diversity indices, Margalef Index and Shannon Weiner Index showed highest values in ST.3, while Simpson Index gave lowest value for that sampling station (Table 1).

Table 1. List of seaweeds found in the three locations of SMI throughout the study period. List arranged in alphabetic order and at the end, three diversity indices were included. Note: the sign '+' indicates the presence of taxa, '++' indicates abundance, and '-' indicates absence.

SL	Group	Species	ST.1	ST.2	ST.3
1	Chlorophyceae	*Avrainvillea amadelpha* (M.) A. Gep. & Gep.	-	+	-
2		*Bryopsis indica* A.Gep. & Gep.	+	++	-
3		*Cladophora prolifera* (Roth) Kütz.	-	+	+
4		*Caulerpa cactoides* (Turner) C. Ag.	-	+	+
5		*Caulerpa chemnitzia* (Esper) Lamx.	-	-	+
6		*Caulerpa racemosa* (Forsskål) J.Ag.	++	++	++
7		*Caulerpa sertularioides* (J. Ag.) Svedelius	+	-	++
8		*Caulerpa taxifolia* (M. Vahl) C. Ag.	+	++	++
9		*Codium geppei* Schmidt	-	-	+
10		*Enteromorpha intestinalis* (L.) Nees	++	+	-
11		*Enteromorpha prolifera* (Müller) J. Ag.	+	-	-
12		*Halimeda discoidea* Decaisne	+	+	+
13		*Halimeda opuntia* (L.) Lamx.	++	+	+
14		*Ulva lactuca* L.	++	+	++
15	Phaeophyceae	*Chnoospora implexa* Hering ex J. Ag.	-	+	++
16		*Dictyota atomaria* Hauck	-	-	+
17		*Dictyopteris australis* Sonders	-	-	++
18		*Hydroclathrus clathratus* (C. Ag.) M. Howe	-	-	+
19		*Padina gymnospora* (Kütz.) Sonder	+	-	++
20		*Padina pavonica* (L.) Thivy	-	+	-
21		*Padina tenuis* Bory	-	-	+

22		*Pocockiella variegata* (Lamx.) Papen.	+	-	+
23		*Sargassum coriifolium* J. Ag.	-	-	++
24		*Sargassum olygocystum* Mont	-	-	++
25		*Sargassum pallidum* (Turner) C. Ag.	-	+	++
26		*Sargassum swartzii* (Turner) C. Ag.	+	++	+
27		*Sargassum tenerrimum* J. Ag.	++	-	+
28		*Sargassum wightii* Greville	+	-	-
29		*Spatoglossum asperum* J. Ag.	+	++	-
30		*Spatoglossum variabile* Figari & De Notaris	-	+	-
31	Rhodophyceae	*Asparagopsis taxiformis* (Del.) Trevisan	-	-	++
32		*Callophyllis variegata* (Bory) Kütz.	-	-	+
33		*Ceramium brevizonatum* Petersen	+	-	-
34		*Chrysymenia agardhii* Harvey	-	-	+
35		*Chondrus crispus* Stackhouse	++	-	++
36		*Corallina officinalis* L.	++	-	-
37		*Dasya corymbifera* J. Ag.	-	++	-
38		*Dasya pedicellata* (C. Ag.) C. Ag.	-	-	+
39		*Dudresnaya hawaiiensis* R.K.S. Lee	-	+	++
40		*Galaxura fastigiata* Decaisne	+	-	+
41		*Gelidium spinosum* (Gmelin) P.C. Silva	+	-	-
42		*Gracilaria spinuligera* Børg.	-	+	-
43		*Halymenia floresia* (Clem.) C. Ag.	+	-	-
44		*Halymenia floridana* J. Ag.	+	-	-
45		*Hypnea boergesenii* Tanaka	+	+	++
46		*Hypnea musciformis* (Wulf.) Lamx.	++	++	++
47		*Liagora ceranoides* Lamx.	-	-	+
48		*Jania ungulata* (Yendo) Yendo	+	+	+
49		*Peyssonnelia polymorpha* (Zanard.) Schmitz	+	+	-
50		*Porphyra nereocystis* Anderson	++	-	-
51		*Vanvoorstia coccinea* Harvey ex J. Ag.	-	-	++
Diversity Indices					
1	Simpson Index		0.82	0.86	0.78
2	Margalef Index		7.15	7.35	8.25
3	Shannon Weiner Index		2.55	2.64	3.25

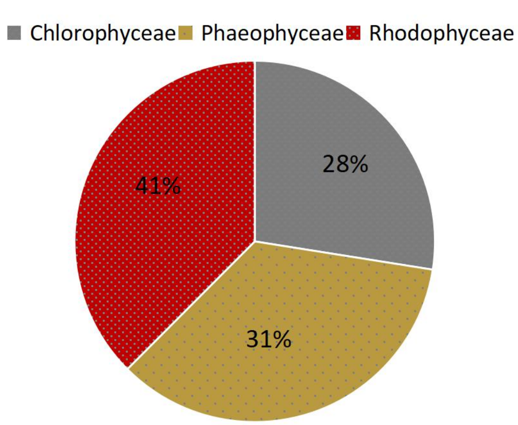

Fig.2. Composition of seaweed species in SMI.

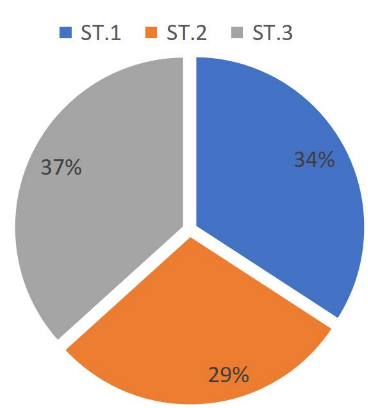

Fig.3. Percentage of total species in all stations.

Physico-chemical Properties

The measured temperature was almost homogeneous in both tides of each season throughout the three stations. It was about 24.68±0.59 and 24.75±0.50 °C in high and low tide respectively in winter, whereas 29.05±0.60 and 29.0±0.43 °C in pre-monsoon (Fig.4). In case of pH, it was highest in ST.3 and the calculated values were pH 8.40±0.11 and 8.58±0.15 in high tide and low tide respectively in winter, while it was pH 8.46±0.11 and 8.64±0.15 in pre-monsoon season. On the other hand, ST.1 showed lowest pH scores, 8.34±0.24 and 8.52±0.24 in winter tides, and 8.40±0.24 and 8.58±0.24 in both tides of pre-monsoon (Fig.5). Measured TDS values showed minimal variations in both tides and seasons at ST.1 and ST.2, but ST.3 gave different TDS patterns during both seasons (Fig.6). The TDS values of ST.3 were 32.80±0.55 and 32.95±0.49 ppt respectively in high tide and low tide of pre-monsoon, which was the observed highest value in this study. Among the three stations, ST.2 showed lowest TDS all time and only the station showed significant variations with ST.3 in both seasons. EC values were almost same in ST.1 and ST.2 but higher in ST.3 in each season. The overall measured EC values were 46.95±0.86 and 47.25±0.83 mS/cm in high tide and low tide of winter, while it was 50.55±0.96 and 52.15±0.89 mS/cm in pre-monsoon in the island (Fig.7).

According to Fig.8, ST.2 and ST.3 showed higher DO values in pre-monsoon than winter season, while ST.1 showed the opposite pattern in DO values. In ST.1, the significant difference was found in low tide of winter with high tide of pre-monsoon, 6.98±0.098 and 6.18±0.088 mg/L respectively. Moreover, ST.2 observed significant difference between high tide of winter (6.18±0.19 mg/L) and low tide of pre-monsoon (6.91±0.17 mg/L) in DO values.

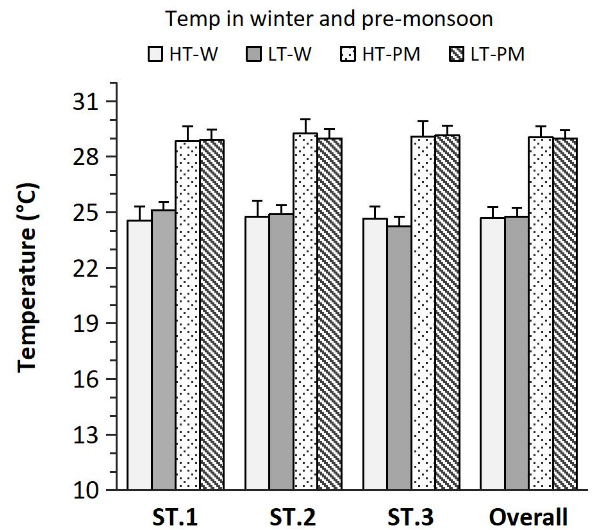

Fig.4. Measured temperature in SMI.

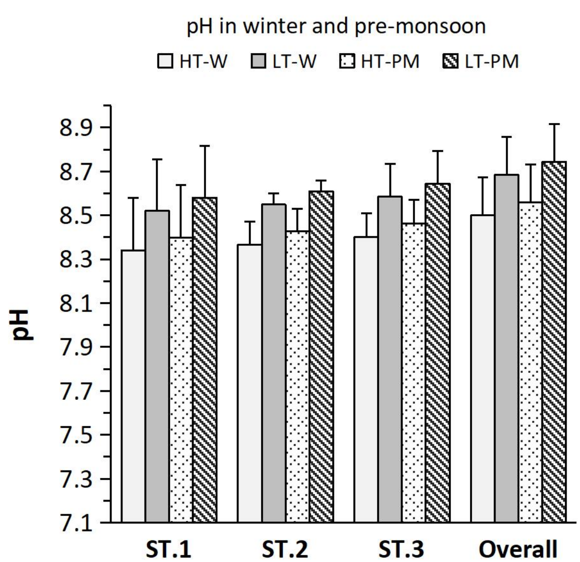

Fig.5. Measured pH values in SMI.

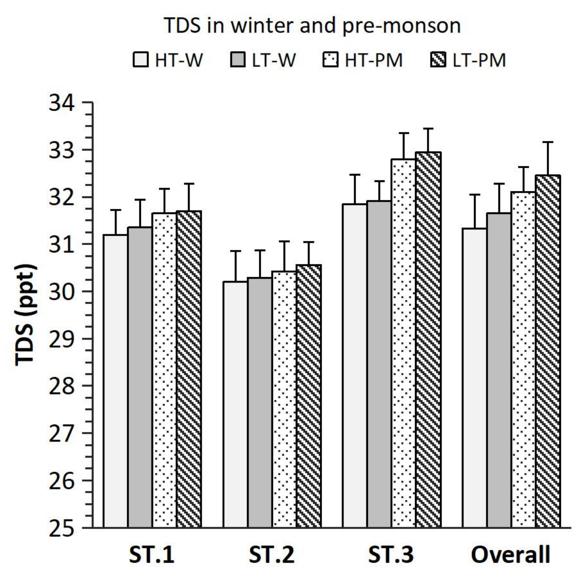

Fig.6. Measured TDS in SMI.

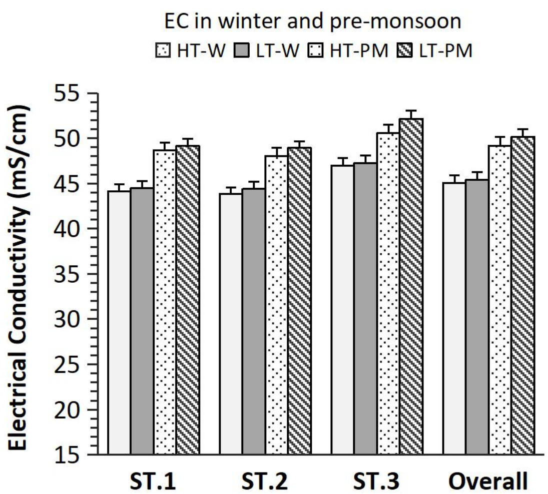

Fig.7. Measured EC values in SMI

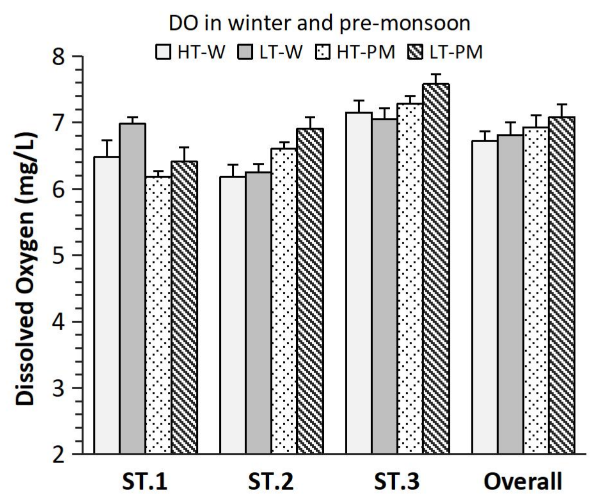

Fig.8. Measured DO in SMI

Table 2. Calculated correlations among water physico-chemical properties and seaweed groups in SMI. Note, ** indicates statistical significance ($P \leq 0.05$).

Para-meters	Temp (^{0}C)	pH	TDS	EC	DO	CHL	PHP	RHP
Temp	1							
pH	0.567**	1						
TDS	-0.358	0.315	1					
EC	0.618**	0.667**	0.855**	1				
DO	-0.125	0.216	0.157	0.168	1			
CHL	-0.235	0.275	-0.521**	-0.212	0.682**	1		
PHP	-0.536**	-0.114	0.331	0.148	0.386	0.253	1	
RHP	-0.326	-0.215	0.545**	0.224	0.586**	0.185	0.577**	1

Correlation Studies

Correlations among the water physico-chemical properties and seaweed groups were determined statistically, and found the current pH of the island depends upon the temperature (r= 0.567) as well as on the electrical conductivity (r = 0.667) of the coastal water regardless of seasons. At the same time, the EC values found positively correlated with the water temperature (r = 0.618) and with total dissolved solids (r = 0.855). In case of dissolved oxygen, there was not found any significant correlations among the other water physico-chemical properties in the island. However, the Chlorophyceae were found TDS sensitive (r = -0.521), but DO responsive (r = 0.682). Higher temperature was limiting factor for occurrence of Phaeophyceae grouped seaweeds in the island (r = -0.536), and it showed positive correlation with other group Rhodophyceae (r = 0.577). Furthermore, the increase of TDS and DO values are responsible with the occurrence of Rhodopyceae algae in the island (r = 0.545 and 0.586 respectively) (Table 2).

DISCUSSION

As a reliable tool to assess the quality of an ecosystem, species diversity has gained much attention, and it can be quantified by measuring richness and evenness or relative abundance of the species in a particular area (25,26). This study determined the diversity of seaweeds and showed as a major algal group Rhodopyceae was dominating and as a single genus *Sargassum* was abundant in the island. It was also depicted that some species were limited according to locations, while some were found commonly through the all sampling stations. Presently, southern part of the island consisted maximum seaweed species and their relative abundance was comparatively higher. It was also conspicuous by Simpson index and Shannon Weiner index; because the indices mathematically showed that the species richness and their relative abundance or evenness was higher in southern part than northwestern and middle coast of the island. Even, in terms of species richness only, Margalef index followed the other two indices that emphasized the seaweed diversity was rich in the southern part of the island. The study observed higher amount of rocky substratum in the area than the other two locations and it would be a probable reason to support a wide range of seaweed species in the area. Moreover, the results of water physico-chemical properties may also support this statement, because it was reported that a range of salinity, pH and temperature are required for supporting better seaweed growth and the study found comparatively better results in southern part according to prescribed value (27,28). Besides, correlation studies said that DO is responsible for two groups of seaweeds availability in the island and the value of the DO was also higher in southern part. There was not found any variations in temperature significantly in respect of locations, but the variations found only due to the seasonal changes in atmospheric conditions in the island (29).

The tidal activities had significant impacts on pH values throughout the island of both seasons that may be for tidal variability and other associated chemical factors in the island (30). Feely et al. reported in 2009 that pH of Bay of Bengal will be less than 8.0 in 2050 and 7.8 in 2095, and the present level of pH in the island was above the reported range (31). Variations in salinity in Bay of Bengal were reported earlier (32). This study also observed non-significant variations in salinity due to locations change except in southern area. There was no significant differences in DO values due to change of seasons, tides or locations, although significant changes were observed in marine ecosystems (33,34). The correlation studies said that presence of Phaeophyceae was assisted by the availability of Rhodophyceae, but declined by increasing temperature. That means, global warming could reduce the both groups of seaweed in the island. On the other hand, increased TDS could decline the availability of Chlorophyceae in the island. There was also found some relation among the physico-chemical parameters except DO. That means the ecosystem is depended on the complex interactions among the physico-chemical parameters and the seaweeds.

However, the overall physico-chemical properties were found in good conditions yet, which meant the island has still the potentiality to start seaweed farming by its entire coasts. As the number of seaweed species of Bangladesh is not fixed yet; this present list will help to enrich this database.

CONFLICT OF INTEREST

All authors declared no conflict of interests.

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