Indian Journal of Geo Marine Sciences
Vol. 49 (8), August 2020, pp. 1379-1388

Diversity and occurrence of seaweeds from the south-eastern coast of Bangladesh

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Received 11 September 2018; revised 13 August 2019

The present investigation was carried out to prepare a checklist of the seaweeds along with the diversity and distribution pattern in the south-eastern Bangladesh coast. The study was performed in the northern Bay of Bengal during October 2015 to April 2018. From the findings of the present study, it was observed that seaweeds did not occur permanently. Some species were observed only for short periods while other species were recorded for 5-7 months. A total of 117 species were recorded, amongst these 62 species belong to the Rhodophyta group, 31 species belong to the Phaeophyta and 24 species belong to the Chlorophyta group. The species occurrence varied both spatially and temporally. Highest diversity (102 species) of species recorded in Saint Martin Island while the lowest diversity (09 species) was found in Bakkhali, Cox's Bazar coast. This study provides a complete species list to fill up information lacking regarding the ecology of seaweeds in the northern Bay of Bengal coast.

[Keywords: Diversity and distribution, Saint Martin Island, Seaweeds, South-eastern Bangladesh coast]

Introduction

Seaweeds are very primitive non-toxic species lacking true roots, stems and leaves, important for marine ecosystem[1-3]. Seaweeds can be classified into three groups, *viz:* Chlorophyta (green algae), Rhodophyta (red algae) and Phaeophyta (brown algae), respectively[4]. Seaweeds species occur mainly between the tip of the intertidal zone and the maximum depth to which adequate sunlight can penetrate. Seaweeds growing in intertidal zones, creeks and estuaries are highly productive and supporting nursery grounds for a variety of commercial fishes of interest[5].

Currently phyco-colloids (agar and carrageenan) from seaweeds are used commercially in the pharmaceutical, cosmetic and food industries. It contains bioactive substances that are characterized with medicinal and many antibacterial, antiviral and antifungal properties[6]. Seaweeds are widely consumed since they are rich in macro- and micro-nutrients, vitamins and enzymes[7]. They are consumed in many countries as fresh, dried or ingredients in prepared foods[1]. Seaweeds are also used for animal feeds and fertilizers[8].

Diversity, geographical distribution and abundance of seaweeds are known to be influenced by both physical and biological factors[9]. Basic study on taxonomy and ecology of seaweeds provides important information for importance and utilization of seaweeds[10]. Seaweeds are identified based on its pigmentation, photosynthesis storage, motility and composition of the cell wall. Seaweeds species diversity information could provide a baseline for ecological and coastal management, as well as culture and uses of seaweeds. Various researchers worked on the seaweeds abundance, diversity, and utilization worldwide[11-14]. In Bangladesh, very few research was found on seaweeds from the Bangladesh coast. The present study was conducted to develop a mapping of geographical occurrence and to identify distribution pattern of seaweeds in the south-eastern coast of Bangladesh.

Materials and Methods

Study area

Marine macro algae or seaweeds were collected in the forms of drift and live specimens inhabiting in intertidal and shallow sub tidal areas during the low tide along the coast namely Saint Martin (Lat. 20º37'02" N and Long. 92º 19' 42" E), Teknaf (Lat. 20º 49' 12" N and Long. 92º 19' 25" E), Inani (Lat. 21º 8' 14" N and Long. 92º 04' 35" E), Bakkhali (Lat. 21º 28' 29" N and Long. 91º 57' 52" E) and

Sonadia (Lat. 21º 28' 16" N and Long. 91º 55' 11" E) in the south-eastern part of Bangladesh during months of October to April from 2015 to 2018 (Fig. 1). The intertidal zone of the Saint Martin Island is mainly characterized by rocky substrate, composed primarily of dead and live corals. Inani site has the sandy bottom with boulders, pebbles, broken shells. On the other hand, Teknaf, Bakkhali river estuary and Sonadia sites are characterized by sandy to muddy soil.

In Bangladesh, the south-eastern coast is tide-dominated and the tides are semi-diurnal with two high and two low tides each day with unequal tidal amplitudes. The area of intertidal exposure depends on the tidal amplitudes. Thus, duration and area of exposure in the coast in turn not only depend on the tidal amplitude but also on topography.

Sampling and species identification

The study sites were visited fortnightly during low tides in every season (October to April) during the study period (2015 to 2018) and the seaweed samples were collected from the intertidal zone. The seaweeds were collected randomly by skin diving and occasionally by SCUBA diving, usually from waters less than 05 m in depth and taken picture's by a digital camera (SONY DSC-H300) on the sites or in the laboratory. Complete plants with holdfast were detached carefully by hand picking or scrapping then washed thoroughly to remove adhered epiphytes or sand and sorted out species wise, preserved in 5 % (v/v) formaldehyde-seawater solution. Then the seaweed samples were brought to the laboratory by keeping it in polythene bags with tags for identification. All the wet and dry specimens were examined carefully under the light and compound microscopes (Leica DM1000 LED) in the laboratory. Taxonomic determination was made by on the basis of external and internal morphological characters using authentic keys as mentioned by Umamaheswara

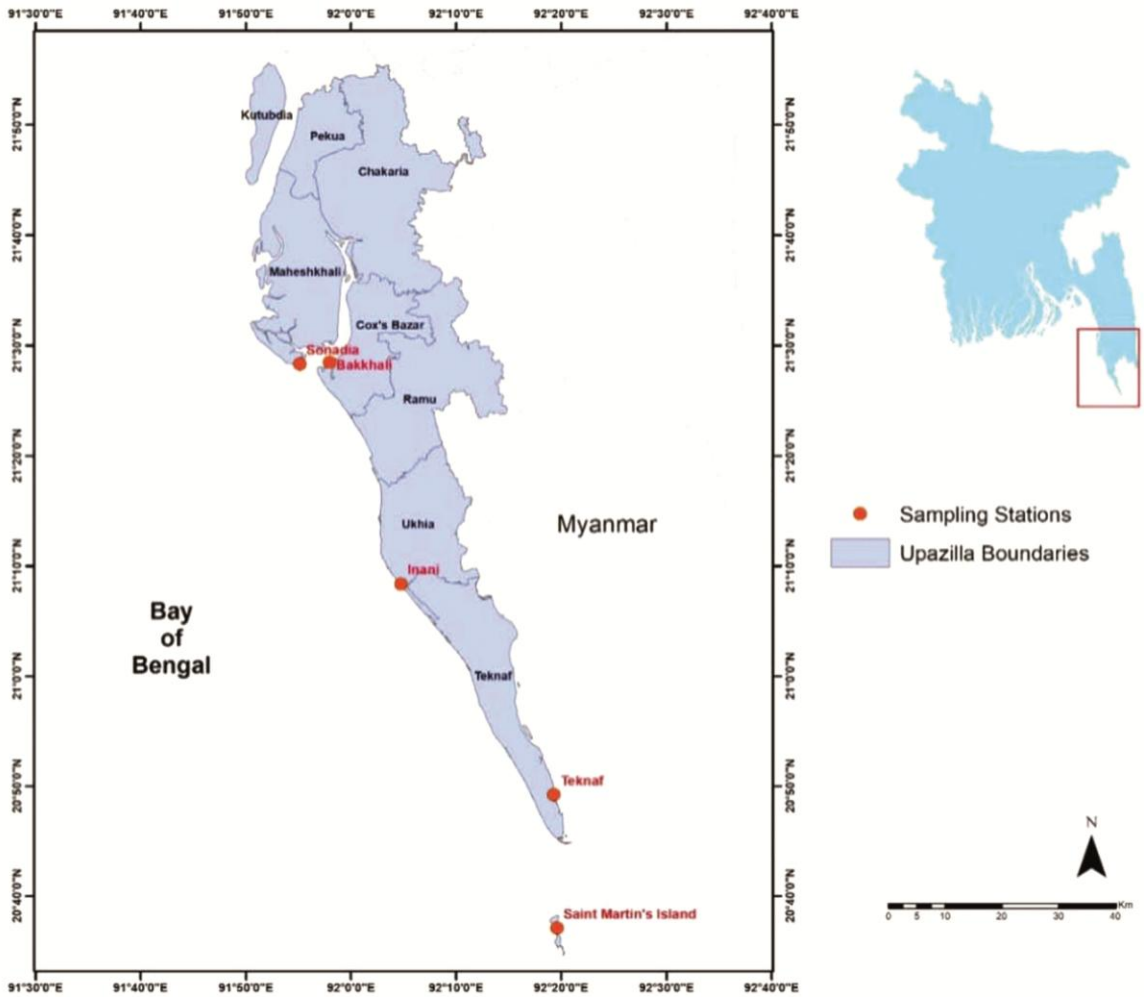

Fig. 1 — Map showing the sampling sites (marked as red circle) in the southeastern coast of Bangladesh.

Rao[15], Calumpong & Meñez[16], Edwards *et al.*[17], standard taxonomy books (Jha *et al.*[18], Sahoo *et al.*[19]) and from the website *www.algaebase.com*. All the herbarium sheets and wet preserved specimens have been deposited at the laboratory of Marine Fisheries Technology Station, BFRI, Cox's Bazar for future reference.

Results and Discussion

A total of 117 species of seaweeds were abundant in the south-eastern coast of Bangladesh. Of which 62 belonged to Rhodophyta (red), 31 were Phaeophyta (brown) and 24 were Chlorophyta (green) (Table 1). Among the recorded seaweeds from the study areas, Rhodophyta contributed 52.99 % species, Phaeophyta 26.50 % and Chlorophyta represented 20.51 % seaweed species (Fig. 2). Most of the seaweed species in the globe are red (6,000 species) followed by brown (2,000 species) and green (1,200 species)[20]. Similarly highest numbers of red seaweeds (47 species out of 114 species) was recorded along the Red Sea coast of Sudan[11]. Moreover, *Hypnea musciformes*, *H. valentiae*, *Enteromorpha intestinalis*, *E. compressa*, *E. torta*, *Chaetomorpha aerea*, and *Ulva reticulate* were observed as common seaweed species in this region.

A total of 197 seaweed species belonging to 95 as red (Rhodophyta), 46 as green (Chlorophyta) and 56 as brown (Phaeophyta) were recorded in Bangladesh coast by some authors[21-25]. On the other hand, 35 taxa of red seaweeds and 45 taxa under 17 genera of green seaweeds have been reported from Bangladesh coasts[26-30]. In marine ecosystem of Kenya, 386 seaweed species (214 red, 116 green and 56 brown seaweeds) with an additional 19 infra-specific taxa were recorded by Bolton *et al.*[12].

In the present study highest numbers of seaweeds taxa were found in the St. Martin Island of Bangladesh coast (Tables 2, 3 & 4). The pictorial view of 3 categories seaweeds i.e. Chlorophyta, Phaeophyta and Rhodophyta are presented in Supplementary Plates 1-3. The seaweed species with the highest diversity observed in the study was red seaweeds, which are the majority of seaweeds taxa worldwide. More than 4,000 seaweeds are recorded in the tropics and this diversity of seaweeds is higher than the temperate region[27]. Saint Martin Island of the south-eastern Bangladesh represented sandy and rocky bottom soil which is protected by the coral with slanting. Moreover; wave action is weak in this coral Island, which created a suitable environment for seaweed species[28]. Occurrence of rocky substratum and geographical location of St. Martin resulted higher diversity and distribution of seaweeds in the region[29]. This might be due to the effects of stable hydrology with high water transparency and rocky structure which support the enormous growth of seaweeds. In contrast, lower diversity of seaweeds was found at Teknaf, Inani, Bakkhali and Sonadia sites, where there were soft bottom substrates (sandy to muddy soil) with high turbidity. The high turbidity is known to limit light intensity that decreases the photosynthetic ability of seaweeds and seagrasses[30]. High turbidity is also known to decrease the ability of spore settlements and growth of seaweeds[31]. Thus, highest abundance and diversity of seaweeds in Saint Martin Island may be due to higher light intensity which increases photosynthesis and growth of seaweeds[32]. In comparison, Teknaf, Bakkhali, Inani and Sonadia are located in the upstream, where, the magnitude of water quality parameters does not remain stable like St. Martin and does not have suitable substratum to

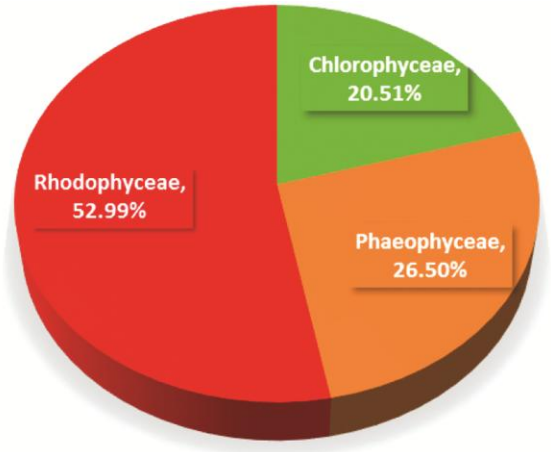

Fig. 2 — Class wise distribution percentage of seaweeds biodiversity in south-eastern Bangladesh coast.

Table 1— List of seaweeds collected from the south-eastern coast of Bangladesh

Taxonomic groups	Chlorophyceae	Phaeophyceae	Rhodophyceae	Total
Order	03	05	13	21
Families	06	05	21	32
Genera	08	10	38	56
Species	24	31	62	117

Table 2 — Distribution of Green algae/Chlorophyta

Sl. No.	Name of the Marine Algae	Sampling sites				
		Saint Martin	Teknaf	Inani	Bakkhali	Sonadia
1	*Caulerpa macrophysa* (Sonder ex Kützing) G. Murray, 1887	√	-	-	-	-
2	*Caulerpa mexicana* Sonder ex Kützing, 1849	√	-	-	-	-
3	*Caulerpa peltata* J.V. Lamouroux, 1809	√	-	-	-	-
4	*Caulerpa racemosa* (Forsskål) J. Agardh, 1873	√	-	-	-	-
5	*Caulerpa sertularioides* (S.G. Gmelin) M. Howe, 1905	√	-	-	-	-
6	*Caulerpa taxifolia* (M. Vahl) C. Agardh, 1817	√	-	-	-	-
7	*Chaetomorpha aerea* (Dillwyn) Kützing, 1849	√	√	√	√	√
8	*Cladophora herpestica* (Montagne) Kützing, 1849	-	-	-	√	√
9	*Cladophora laetevirens* (Dillwyn) Kützing, 1843	√	-	-	-	-
10	*Codium fragile* (Suringar) Hariot, 1889	√	-	-	-	-
11	*Enteromorpha compressa* (Linnaeus) Nees, 1753	√	√	√	√	√
12	*Enteromorpha intestinalis* (Linnaeus) Nees, 1753	√	√	√	√	√
13	*Enteromorpha torta* (Mertens) Reinbold, 1893	√	√	√	√	√
14	*Halimeda discoidea* Decaisne, 1842	√	-	-	-	-
15	*Halimeda gracilis* Harvey ex J. Agardh, 1887	√	-	-	-	-
16	*Halimeda minima* (W.R.Taylor) Hillis-Colinvaux, 1968	√	-	-	-	-
17	*Halimeda opuntia* (Linnaeus) J.V. Lamouroux, 1816	√	-	-	-	-
18	*Halimeda tuna* (J. Ellis & Solander) J.V. Lamouroux, 1816	√	-	-	-	-
19	*Ulva compressa* Linnaeus, 1753	-	√	-	√	√
20	*Ulva conglobata* Kjellman, 1897	-	-	√	-	-
21	*Ulva fasciata* Delile, 1813	√	-	√	-	-
22	*Ulva lactuca* Linnaeus, 1753	√	-	√	-	-
23	*Ulva reticulata* Forsskål, 1775	√	√	√	√	√
24	*Valoniopsis pachynema* (G. Martens) Børgesen, 1934	-	-	√	-	-

Table 3 — Distribution of Brown algae/Phaeophyta

Sl. No.	Name of the Marine Algae	Sampling sites				
		Saint Martin	Teknaf	Inani	Bakkhali	Sonadia
1	*Colpomenia peregrina* Sauvageau, 1927	√	-	-	-	-
2	*Colpomenia ramosa* W.R. Taylor, 1945	√	√	-	-	-
3	*Colpomenia sinuosa* (Mertens ex Roth) Derbès & Solier, 1851	√	√	-	-	-
4	*Dictyota atomaria* (Woodward) Greville, 1830	√	-	-	-	-
5	*Dictyota ciliolata* Sonder ex Kützing, 1859	√	-	-	-	-
6	*Dictyota dichotoma* (Hudson) J.V. Lamouroux, 1809	√	-	-	-	-
7	*Dictyota flabellata* (Collins) Setchell & N.L. Gardner, 1924	√	-	√	-	-
8	*Dictyota menstrualis* (Hoyt) Schnetter, Hörning & Weber-Peukert, 1987	√	-	-	-	-
9	*Dictyota patens* J. Agardh, 1882	√	√	-	-	-
10	*Ectocarpus siliculosus* (Dillwyn) Lyngbye, 1819	√	-	√	-	-
11	*Hydroclathrus clathratus* (C. Agardh) M. Howe, 1920	√	-	-	-	-
12	*Hydroclathrus tenuis* C.K. Tseng & Lu Baroen, 1983	√	-	-	-	-
13	*Padina antillarum* (Kützing) Piccone, 1886	√	-	-	-	-
14	*Padina australis* Hauck, 1887	√	-	-	-	-
15	*Padina boryana* Thivy, 1966	√	-	-	-	-
16	*Padina fraseri* (Greville) Greville, 1830	√	-	√	-	-
17	*Padina gymnospora* (Kützing) Sonder, 1871	√	-	-	-	-
18	*Padina pavonica* (Linnaeus) Thivy, 1960	√	-	-	-	-
19	*Padina tetrastromatica* Hauck, 1887	√	-	√	-	-
20	*Ralfsia fungiformis* (Gunnerus) Setchell & N.L. Gardner, 1924	√	-	-	-	-
21	*Rosenvingea intricata* (J. Agardh) Børgesen, 1914	√	-	-	-	-
22	*Rosenvingea orientalis* (J. Agardh) Børgesen, 1914	-	√	-	-	-
23	*Rosenvingea sanctae-crucis* Børgesen, 1914	-	√	-	-	-
24	*Sargassum arnaudianum* Montagne, 1850	√	-	√	-	-
25	*Sargassum filipendula* C. Agardh, 1824	√	-	-	-	-
26	*Sargassum ilicifolium* (Turner) C. Agardh, 1820	√	-	-	-	-
27	*Sargassum myriocystum* J. Agardh, 1848	√	-	-	-	-
28	*Sargassum oligocystum* Montagne, 1845	√	-	√	-	-
29	*Sargassum platycarpum* Montagne, 1842	√	-	-	-	-
30	*Spatoglossum asperum* J. Agardh, 1894	√	-	-	-	-
31	*Stypopodium zonale*(J.V. Lamouroux) Papenfuss, 1940	√	-	-	-	-

Table 4 — Distribution of Red algae/Rhodophyta

Sl. No.	Name of the Marine Algae	Sampling sites				
		Saint Martin	Teknaf	Inani	Bakkhali	Sonadia
1	*Acanthophora spicifera* (M. Vahl) Børgesen, 1910	√	-	√	-	-
2	*Actinotrichia fragilis* (Forsskål) Børgesen, 1932	√	-	-	-	-
3	*Amphiroa cryptarthrodia* Zanardini, 1843	√	-	-	-	-
4	*Amphiroa fragilissima* (Linnaeus) J.V. Lamouroux, 1816	√	-	-	-	-
5	*Amphiroa rigida* J.V. Lamouroux, 1816	√	-	-	-	-
6	*Asparagopsis taxiformis* (Delile) Trevisan, 1845	√	-	-	-	-
7	*Bangia fuscopurpurea* (Dillwyn) Lyngbye, 1819	√	√	√	-	-
8	*Champia parvula* (C. Agardh) Harvey, 1853	√	-	-	-	-
9	*Chondrus crispus* Stackhouse, 1797	-	-	√	-	-
10	*Chrysymenia* sp., Decaisne, 1842	√	-	-	-	-
11	*Dermonema pulvinatum* (Grunow) Fan, 1962	√	-	√	-	-
12	*Dichotomaria obtusata* (J. Ellis & Solander) Lamarck, 1816	√	-	-	-	-
13	*Dudresnaya verticillata* (Withering) Le Jolis, 1863	√	-	-	-	-
14	*Eucheuma cottonii* Weber-van Bosse, 1913	√	-	-	-	-
15	*Eucheuma spinosum* J. Agardh, nom. illeg., 1852	√	-	-	-	-
16	*Galaxaura oblongata* (J. Ellis & Solander) J.V. Lamouroux, 1816	√	-	-	-	-
17	*Galaxaura rugosa* (J. Ellis & Solander) J.V. Lamouroux, 1816	√	-	-	-	-
18	*Ganonema pinnatum* (Harvey) Huisman, 2002	-	-	√	-	-
19	*Gelidium pusillum* (Stackhouse) Le Jolis, 1863	√	-	-	-	-
20	*Gracilaria corticata* (J. Agardh) J. Agardh,1852	-	-	√	-	-
21	*Gracilaria tikvahiae* McLachlan, 1979	-	-	√	-	-
22	*Gracilaria verrucosa* (Hudson) Papenfuss, nom. rejic, 1950	-	-	√	-	-
23	*Grateloupia lanceolata* (Okamura) S. Kawaguchi, 1997	√	-	-	-	-
24	*Grateloupia livida* (Harvey) Yamada, 1931	-	√	√	-	-
25	*Halymenia dilatata* Zanardini, 1851	√	-	-	-	-
26	*Halymenia venusta* Børgesen, 1932	√	-	-	-	-
27	*Helminthocladia australis* Harvey, 1863	-	-	√	-	-
28	*Hildenbrandia rubra* (Sommerfelt) Meneghini, 1841	√	-	-	-	-
29	*Hydrolithon onkodes* (Heydrich) Penrose & Woelkerling, 1992	√	-	-	-	-
30	*Hypnea cornuta* (Kützing) J. Agardh, 1851	√	√	√	-	-
31	*Hypnea esperi* Bory, nom. illeg, 1828	√	-	-	-	-
32	*Hypnea flexicaulis* Y. Yamagishi & M. Masuda, 2000	√	-	√	-	-
33	*Hypnea musciformis* (Wulfen) J.V. Lamouroux, 1813	√	√	√	√	√
34	*Hypnea pannosa* J. Agardh, 1847	√	-	-	-	-
35	*Hypnea valentiae* (Turner) Montagne, 1841	√	√	√	√	√
36	*Jania rubens* (Linnaeus) J.V. Lamouroux, 1816	√	-	-	-	-
37	*Kappaphycus alvarezii* (Doty) Doty ex P.C. Silva, 1996	√	-	-	-	-
38	*Laurencia pinnata* Yamada, 1931	√	-	-	-	-
39	*Liagora albicans* J.V. Lamouroux, 1816	-	-	√	-	-
40	*Liagora ceranoides* J.V. Lamouroux, 1816	√	-	-	-	-
41	*Liagora donaldiana* I.A. Abbott & Huisman, 2003	√	-	-	-	-
42	*Liagora hawaiiana* Butters, 1911	√	-	-	-	-
43	*Liagora perennis* I.A. Abbott, 1995	√	-	-	-	-
44	*Liagora tetrasporifera* Børgesen, 1927	√	-	-	-	-
45	*Liagora valida* Harvey, 1853	√	-	-	-	-

(*Contd*.)

Table 4 — Distribution of Red algae/Rhodophyta (*Contd*.)

Sl. No.	Name of the Marine Algae	Sampling sites				
		Saint Martin	Teknaf	Inani	Bakkhali	Sonadia
46	*Liagora viscida* (Forsskål) C. Agardh, 1822	√	-	-	-	-
47	*Lithophyllum kotschyanum* Unger, 1858	√	-	-	-	-
48	*Lithophyllum okamurae* Foslie, 1900	√	-	-	-	-
49	*Lithothamnion glaciale* Kjellman, 1883	√	-	-	-	-
50	*Nemalion helminthoides* (Velley) Batters, 1902	-	-	√	-	√
51	*Palmaria palmata* (Linnaeus) F. Weber & D. Mohr, 1805	√	-	-	-	-
52	*Peyssonnelia polymorpha* (Zanardini) F. Schmitz, 1841	√	-	-	-	-
53	*Peyssonnelia squamaria* (S.G. Gmelin) Decaisne ex J. Agardh,1842	√	-	-	-	-
54	*Porphyra indica* V. Krishnamurthy & M. Baluswami, 1824	√	-	-	-	-
55	*Porphyra vietnamensis* Tak.Tanaka & Pham-Hoàng Ho, 1962	√	-	-	-	-
56	*Scinaia complanata* (Collins) A.D. Cotton,1907	√	-	-	-	-
57	*Solieria robusta* (Greville) Kylin, 1932	√	-	-	-	-
58	*Spermothamnion repens* (Dillwyn) Magnus, 1932	√	-	-	-	-
59	*Titanophycus validus* (Harvey) Huisman, G.W. Saunders & A.R. Sherwood, 2006	√	-	-	-	-
60	*Tolypiocladia glomerulata* (C. Agardh) F. Schmitz, 1897	√	-	-	-	-
61	*Tricleocarpa cylindrica* (J. Ellis & Solander) Huisman & Borowitzka, 1990	√	-	-	-	-
62	*Tricleocarpa fragilis* (Linnaeus) Huisman & R.A.Townsend, 1993	√	-	-	-	-

Table 5 — Monthly distribution pattern of seaweeds (Chlorophyta)

Sl. No.	Name of the Marine Algae	Months (2015-2018)						
		Oct	Nov	Dec	Jan	Feb	Mar	Apr
1	*Caulerpa macrophysa* (Sonder ex Kützing) G. Murray, 1887	-	-	-	+	+	+	-
2	*Caulerpa mexicana* Sonder ex Kützing, 1849	-	-	-	-	+	+	
3	*Caulerpa peltata* J.V. Lamouroux, 1809	-	-	-	-	+	+	-
4	*Caulerpa racemosa* (Forsskål) J. Agardh, 1873	-	-	-	+	+	+	+
5	*Caulerpa sertularioides* (S.G. Gmelin) M. Howe, 1905	-	-	-	-	+	+	+
6	*Caulerpa taxifolia* (M. Vahl) C. Agardh, 1817	-	-	-	-	+	+	+
7	*Chaetomorpha aerea* (Dillwyn) Kützing, 1849	+	+	+	+	+	+	+
8	*Cladophora herpestica* (Montagne) Kützing, 1849	-	-	+	+	+	+	-
9	*Cladophora laetevirens* (Dillwyn) Kützing, 1843	-	-	-	+	+	+	-
10	*Codium fragile* (Suringar) Hariot, 1889	-	-	-	-	+	+	
11	*Enteromorpha compressa* (Linnaeus) Nees, 1753	+	+	+	+	+	+	+
12	*Enteromorpha intestinalis* (Linnaeus) Nees, 1753	-	-	+	+	+	+	+
13	*Enteromorpha torta* (Mertens) Reinbold, 1893	-	-	+	+	+	+	-

(*Contd*.)

form an enormous growth of natural seaweeds colony. The salinity of seawater is very prudent and potential factor for growth of seaweeds, as it is the major determinate of osmotic balance. Lower growth of *Hypnea* sp. was observed from Saint Martin when salinity dropped below 24 ppt and better growth reported when water salinity increased >30 ppt[33]. Similarly, observed salinity ranging from 27-33 ppt along St. Martin, Inani and Bakkhali sites which did not deplete below 30 ppt in St. Martin[34]. So, a stable and moderate salinity was one of the key factors for having highest biomass of seaweeds in St. Martin. Water salinity has a strong positive correlation with water pH, DO and water transparency[34].

Diversity, geographical distribution and growth of seaweeds are governed by various environmental factors like water temperature, salinity, pH, dissolved oxygen, water transparency, and nutrients etc.[35]. Specific water quality parameters are essential for distribution, propagation and growth of seaweeds[36]. Required water quality for seaweeds spore settlement and growth remain during October to April months that might be the main cause of seaweed availability in the Bangladesh coast and seaweeds are mostly found in those months (Tables 5, 6 & 7). Moreover, as the water quality remains in favorable conditions for seaweeds growth, the highest numbers of seaweeds were found from January to March in our coast.

Table 5 — Monthly distribution pattern of seaweeds (Chlorophyta) (*Contd*.)

Sl. No.	Name of the Marine Algae	Months (2015-2018)						
		Oct	Nov	Dec	Jan	Feb	Mar	Apr
14	*Halimeda discoidea* Decaisne, 1842	-	-	+	+	+	-	-
15	*Halimeda gracilis* Harvey ex J. Agardh, 1887	-	-	-	-	+	+	-
16	*Halimeda minima* (W.R.Taylor) Hillis-Colinvaux, 1968	-	-	-	+	+	-	-
17	*Halimeda opuntia* (Linnaeus) J.V. Lamouroux, 1816	-	-	-	+	+	-	-
18	*Halimeda tuna* (J. Ellis & Solander) J.V. Lamouroux, 1816	-	-	-	+	+	+	-
19	*Ulva compressa* Linnaeus, 1753	-	+	+	+	+	+	+
20	*Ulva conglobata* Kjellman, 1897	-	-	-	+	+	+	-
21	*Ulva fasciata* Delile, 1813	-	-	-	+	+	+	-
22	*Ulva lactuca* Linnaeus, 1753	-	-	-	+	+	+	-
23	*Ulva reticulata* Forsskål, 1775	-	-	+	+	+	+	-
24	*Valoniopsis pachynema* (G.Martens) Børgesen, 1934	-	-	-	+	+	+	-

+ Present -Absent

Table 6 — Monthly distribution pattern of seaweeds (Phaeophyta)

Sl. No.	Name of the Marine Algae	Months (2015-2018)						
		Oct	Nov	Dec	Jan	Feb	Mar	Apr
1	*Colpomenia peregrina* Sauvageau, 1927	-	+	+	+	+	-	-
2	*Colpomenia ramosa* W.R. Taylor, 1945	-	-	+	+	+	-	-
3	*Colpomenia sinuosa* (Mertens ex Roth) Derbès & Solier, 1851	-	+	+	+	+	-	-
4	*Dictyota atomaria* (Woodward) Greville, 1830	-	-	-	-	+	+	-
5	*Dictyota ciliolata* Sonder ex Kützing, 1859	-	-	-	-	+	+	+
6	*Dictyota dichotoma* (Hudson) J.V. Lamouroux, 1809	-	-	+	+	+	-	-
7	*Dictyota flabellata* (Collins) Setchell & N.L. Gardner, 1924	-	-	-	-	+	+	-
8	*Dictyota menstrualis* (Hoyt) Schnetter, Hörning & Weber-Peukert, 1987	-	-	-	+	+	+	-
9	*Dictyota patens* J. Agardh, 1882	-	-	-	-	+	+	-
10	*Ectocarpus siliculosus* (Dillwyn) Lyngbye, 1819	-	-	-	+	+	+	-
11	*Hydroclathrus clathratus* (C. Agardh) M. Howe, 1920	-	-	+	+	+	-	-
12	*Hydroclathrus tenuis* C.K. Tseng & Lu Baroen, 1983	-	-	+	+	+	-	-
13	*Padina antillarum* (Kützing) Piccone, 1886	-	-	-	+	+	+	-
14	*Padina australis* Hauck, 1887	-	-	-	+	+	+	-
15	*Padina boryana* Thivy, 1966	-	-	-	+	+	+	-
16	*Padina fraseri (*Greville) Greville, 1830	-	-	-	+	+	+	+
17	*Padina gymnospora* (Kützing) Sonder, 1871	-	-	-	+	+	+	-
18	*Padina pavonica* (Linnaeus) Thivy, 1960	-	-	-	+	+	+	-
19	*Padina tetrastromatica* Hauck, 1887	-	-	-	+	+	+	+
20	*Ralfsia fungiformis* (Gunnerus) Setchell & N.L. Gardner, 1924	-	-	-	+	+	+	+
21	*Rosenvingea intricata* (J. Agardh) Børgesen, 1914	-	-	-	+	+	+	-
22	*Rosenvingea orientalis* (J. Agardh) Børgesen, 1914	-	-	-	+	+	+	-
23	*Rosenvingea sanctae-crucis* Børgesen, 1914	-	-	-	-	+	+	-
24	*Sargassum arnaudianum* Montagne, 1850	-	-	-	+	+	+	-
25	*Sargassum filipendula* C. Agardh, 1824	-	-	-	-	+	+	-
26	*Sargassum ilicifolium* (Turner) C. Agardh, 1820	-	-	-	-	+	+	-
27	*Sargassum myriocystum* J. Agardh, 1848	-	-	-	-	+	+	+
28	*Sargassum oligocystum* Montagne, 1845	-	-	-	+	+	+	+
29	*Sargassum platycarpum* Montagne, 1842	-	-	-	-	+	+	-
30	*Spatoglossum asperum* J. Agardh, 1894	-	-	+	+	+	+	-
31	*Stypopodium zonale* (J.V. Lamouroux) Papenfuss, 1940	-	-	-	-	+	+	+

+ Present -Absent

Table 7 — Monthly distribution pattern of seaweeds (Rhodophyta)

Sl. No.	Name of the Marine Algae	Months (2015-2018)						
		Oct	Nov	Dec	Jan	Feb	Mar	Apr
1	*Acanthophora spicifera* (M. Vahl) Børgesen, 1910	-	-	+	+	+	-	-
2	*Actinotrichia fragilis* (Forsskål) Børgesen, 1932	-	-	-	+	+	-	-
3	*Amphiroa cryptarthrodia* Zanardini, 1843	-	-	-	-	+	+	+
4	*Amphiroa fragilissima* (Linnaeus) J.V. Lamouroux, 1816	-	-	+	+	+	-	-
5	*Amphiroa rigida* J.V. Lamouroux, 1816	-	-	-	+	+	+	-
6	*Asparagopsis taxiformis* (Delile) Trevisan, 1845	-	-	+	+	+	+	-
7	*Bangia fuscopurpurea* (Dillwyn) Lyngbye, 1819	-	+	+	+	+	+	
8	*Champia parvula* (C.Agardh) Harvey, 1853	-	-	-	+	+	-	-
9	*Chondrus crispus* Stackhouse, 1797	-	-	-	-	+	+	-
10	*Chrysymenia* sp., 1842	-	-	-	+	+	+	-
11	*Dermonema pulvinatum* (Grunow) Fan, 1962	-	-	-	-	+	+	-
12	*Dichotomaria obtusata* (J. Ellis & Solander) Lamarck, 1816	-	-	-	-	+	+	-
13	*Dudresnaya verticillata* (Withering) Le Jolis, 1863	-	-	-	+	+	+	-
14	*Eucheuma cottonii* Weber-van Bosse, 1913	-	-	-	+	+	+	
15	*Eucheuma spinosum* J. Agardh, nom. illeg, 1852	-	-	-	+	+	+	-
16	*Galaxaura oblongata* (J. Ellis & Solander) J.V. Lamouroux, 1816	-	-	-	-	+	+	+
17	*Galaxaura rugosa* (J. Ellis & Solander) J.V. Lamouroux, 1816	-	-	-	-	+	+	+
18	*Ganonema pinnatum* (Harvey) Huisman, 2002	-	-	-	-	+	+	-
19	*Gelidium pusillum* (Stackhouse) Le Jolis, 1863	-	-	+	+	+	+	-
20	*Gracilaria corticata* (J.Agardh) J. Agardh,1852	-	-	-	+	+	+	-
21	*Gracilaria tikvahiae* McLachlan, 1979	-	-	-	+	+	-	-
22	*Gracilaria verrucosa* (Hudson) Papenfuss, nom. rejic, 1950	-	-	-	-	+	+	-
23	*Grateloupia lanceolata* (Okamura) S. Kawaguchi, 1997	-	-	-	+	+	+	-
24	*Grateloupia livida* (Harvey) Yamada, 1931	-	-	-	+	+	+	-
25	*Halymenia dilatata* Zanardini, 1851	-	-	-	-	+	+	-
26	*Halymenia venusta* Børgesen, 1932	-	-	-	-	+	+	-
27	*Helminthocladia australis* Harvey, 1863	-	-	-	+	+	+	-
28	*Hildenbrandia rubra* (Sommerfelt) Meneghini, 1841	-	-	-	+	+	+	+
29	*Hydrolithon onkodes* (Heydrich) Penrose & Woelkerling, 1992	-	-	+	+	+	+	-
30	*Hypnea cornuta* (Kützing) J. Agardh, 1851	-	-	+	+	+	+	-
31	*Hypnea esperi* Bory, nom. illeg, 1828	-	-	-	+	+	+	+
32	*Hypnea flexicaulis* Y. Yamagishi & M. Masuda, 2000	-	-	+	+	+	+	-
33	*Hypnea musciformis* (Wulfen) J.V. Lamouroux, 1813	+	+	+	+	+	+	+
34	*Hypnea pannosa* J. Agardh, 1847	-	-	-	+	+	+	+
35	*Hypnea valentiae* (Turner) Montagne, 1841	-	-	-	+	+	+	-
36	*Jania rubens* (Linnaeus) J.V. Lamouroux, 1816	-	-	+	+	+	-	-
37	*Kappaphycus alvarezii* (Doty) Doty ex P.C. Silva, 1996	-	-	-	+	+	+	-
38	*Laurencia pinnata* Yamada, 1931	-	-	-	-	+	+	+
39	*Liagora albicans* J.V. Lamouroux, 1816	-	-	-	-	+	+	-
40	*Liagora ceranoides* J.V. Lamouroux, 1816	-	-	-	+	+	-	-
41	*Liagora donaldiana* I.A. Abbott & Huisman, 2003	-	-	-	-	+	+	+
42	*Liagora hawaiiana* Butters, 1911	-	-	-	+	+	+	-
43	*Liagora perennis* I.A. Abbott, 1995	-	-	-	-	+	+	-
44	*Liagora tetrasporifera* Børgesen, 1927	-	-	-	-	+	+	-
45	*Liagora valida* Harvey, 1853	-	-	-	-	+	+	-
46	*Liagora viscida* (Forsskål) C. Agardh, 1822	-	-	-	-	+	+	+

(*Contd*.)

Table 7 — Monthly distribution pattern of seaweeds (Rhodophyta) (*Contd*.)

Sl. No.	Name of the Marine Algae	Months (2015-2018)						
		Oct	Nov	Dec	Jan	Feb	Mar	Apr
47	*Lithophyllum kotschyanum* Unger, 1858	-	-	-	+	+	+	+
48	*Lithophyllum okamurae* Foslie, 1900	-	-	-	-	+	+	+
49	*Lithothamnion glaciale* Kjellman, 1883	-	-	-	+	+	+	+
50	*Nemalion helminthoides* (Velley) Batters, 1902	-	-	-	-	+	+	-
51	*Palmaria palmata* (Linnaeus) F. Weber & D. Mohr, 1805	-	-	-	-	+	+	+
52	*Peyssonnelia polymorpha* (Zanardini) F. Schmitz, 1841	-	-	-	+	+	+	+
53	*Peyssonnelia squamaria* (S.G. Gmelin) Decaisne ex J. Agardh,1842	-	-	-	+	+	+	+
54	*Porphyra indica* V. Krishnamurthy & M. Baluswami, 1824	-	-	-	+	+	+	-
55	*Porphyra vietnamensis* Tak. Tanaka & Pham-Hoàng Ho, 1962	-	-	-	-	+	+	+
56	*Scinaia complanata* (Collins) A.D. Cotton,1907	-	-	-	-	+	+	+
57	*Solieria robusta* (Greville) Kylin, 1932	-	-	-	-	+	+	+
58	*Spermothamnion repens* (Dillwyn) Magnus, 1932	-	-	-	+	+	+	-
59	*Titanophycus validus* (Harvey) Huisman, G.W. Saunders & A.R. Sherwood, 2006	-	-	-	+	+	+	-
60	*Tolypiocladia glomerulata* (C. Agardh) F. Schmitz, 1897	-	-	-	+	+	+	+
61	*Tricleocarpa cylindrica* (J. Ellis & Solander) Huisman & Borowitzka, 1990	-	-	-	+	+	+	-
62	*Tricleocarpa fragilis* (Linnaeus) Huisman & R.A.Townsend, 1993	-	-	-	+	+	+	-

+ Present -Absent

Similar observation was also recorded in many Asian countries[37]. Thus, our study also recorded higher diversity of red seaweeds than other groups of seaweeds in Bangladesh coast (Table 7). The diversity of seaweeds in the southeast coast of Bangladesh showed that the members of Rhodophyta were dominant followed by Phaeophyta and Chlorophyta.

Conclusions

To date, there is no extensive assessment of the diversity and distribution of seaweeds along the Bangladesh coast. The seaweeds checklist and its distribution pattern are prerequisite for the future research and conserves their diversity from being depletion. To make the occurrence of seaweeds in Bangladesh coast in a sustainable manner more comprehensive research on important seaweeds and their utilization have to be conducted.

Supplementary Data

Supplementary data associated with this article is available in the electronic form at http://nopr.niscair.res.in/jinfo/ijms/IJMS_49(08)1379-1388_SupplData.pdf

Acknowledgements

The authors are thankful to Bangladesh Fisheries Research Institute for providing research facilities and financial support under its core research fund to Marine Fisheries & Technology Station, Cox's Bazar. Thanks to Ahmed Tahmid for the drawing of the location map of study area.

Conflict of Interest Statement

The authors declare no conflicts of interest.

Author Contributions

MEH and MZA conceived and designed the research. MMI, SJH and ASMS led sample collection and identification and authentication of the observed samples. MSB contributed to data analyses and illustrations. MMI, ASM S and MSB wrote the manuscript. MEH revised the manuscript. All the authors edited and approved the manuscript.

References

1 Ahmed N & Taparhudee W, *Seaweed Cultivation in Bangladesh: Problems and Potentials*, Kasetsart University Fisheries Research Bulletin, 28, (2005).

2 Nybakken J W, *Marine biology an ecological approach*, Fourth edition (Addison Wesley Edu. Pub. Inc) 2001, pp. 481.

3 Zemke-White W L & Ohno M, World seaweed utilization: an end-of-century summary, *J Appl Phycol*, 11 (4) (1999) 369-379.

4 Newman D J, Cragg G M, Natural products as sources of new drugs over the 30 years from 1981 to 2010, *J Nat Prod*, 75 (2012) 311.

5 Coppejans E, Richmond M D, Clerck O de & Rabesandratana R, Marine macroalgae: Seaweeds, In: *A guide to the seashores of Eastern Africa and the Western Indian Ocean Islands*, edited by M D Richmond, (SIDA, Department for Research Cooperation, SAREC), 1997, pp. 70-97.

6 Flora G & Maria Victoria Rani S, An approach towards control of blast by foliar application of seaweed concentrate, *Sci Res Report*, 2 (3) (2012) 213-217.

7 Robledo D & Freile-Pelegrin Y, Chemical and mineral composition of six potentially edible seaweed species of Yucatan, *Bot Mar*, 40 (1997) 301-306.

8 Goulart F, Eating seaweeds can be a healthy practice, *Underwater USA*, 6 (4) (1989) 26-27.

9 Lobban, C S & Harrison P J, Seaweed Ecology and Physiology, (Cambridge University Press, New York) 1994, pp. 366.

10 Prud'homme van Reine W F & Trono Jr G C, *Plant resources of South-East Asia* 15 (1) *Cryptogams: Algae*. (Backhuys Publishers, Leiden, The Netherlands) 2001, pp. 318

11 Osman N A R & Mohammed S E, A compiled checklist of seaweeds of Sudanese Red Sea coast, *J Coast Life Med*, 4 (2) (2016) 114-120.

12 Bolton J J, Oyieke, H A & Gwada P, The seaweeds of Kenya: Checklist, history of seaweed study, coastal environment, and analysis of seaweed diversity and biogeography, *S Afr J Bot*, 73 (2007) 76-88.

13 Brodie J, & Irvine L M, *Seaweeds of the British Isles*, Rhodophyta. Part 3B *Bangiophycidae*, Intercept, Andover (2003) 1-167.

14 Coppejans E & Beeckman T, Caulerpa section Sedoideae (Chlorophyta, Caulerpales) from the Kenya coast, *Nova Hedwigia*, 49 (1989) 381–393.

15 Umamaheswara Rao M, Key for identification of economically important seaweeds, *CMFRI Bull*, 41 (1987) 19-25.

16 Calumpong H P & Menez E G, *Field guide to the common mangroves, sea grasses and algae of the Philippines*, (Bookmark Inc, Makati, Philippines), 1997, pp. 197.

17 Edwards M, Hanniffy D, Heesch S, Hernandez-Kantun J, Moniz B M, *et al.*, *Macro algae Fact-sheets*. Soler-Vila A & Moniz M ed, (2012) pp. 40.

18 Jha B, Reddy C R K & Thakur M U R, Seaweeds of India, In: *The diversity and distribution of seaweeds of Gujarat Coast*, (Developments in Applied Phycology, Springer, Dordrecht) 2009, pp. 216.

19 Sahoo D, Sahoo N & Bhattacharya D, *Seaweeds of Indian coast*, (A P H Publication, New Delhi) 2001, pp. 283.

20 Robinson R K, Algae as a crop, *World Crop*, 32 (1) (1980), 8-14.

21 Islam A K M N & Begum Z N T (eds.), *Encyclopedia of Flora and Fauna of Bangladesh*. Vol. 4. Algae, Charophyta-Rhodophyta, (Achnanthaceae- Vaucheriaceae). (Asiat. Soc. Bangladesh, Dhaka) 2009, pp. 543.

22 Islam A K M N, Aziz A, Khondker M, Alfasane M A, *et al.* (eds.), *Encyclopedia of Flora and Fauna of Bangladesh*, Vol 3. Algae, Chlorophyta (Aphanochaetaceae-Zygnemataceae), (Asia Soc Bangladesh, Dhaka), 2008, pp. 812.

23 Islam S, Aziz A & Chowdhury A H, Marine algae of St. Martin's Island, Bangladesh. VIII. New records of Red algae (Rhodophyceae), *Bangladesh J Bot*, 39 (1) (2010) pp. 87-96.

24 Aziz A & Rahman M T, Marine algae of the St. Martin's Island, Bangladesh. XI. Red algae (Rhodophyceae), *Bangladesh J Bot*, 39 (2) (2010) pp. 161-168.

25 Aziz A & Rahman M T, Marine algae of the St. Martin's Island, Bangladesh. XII. New records of Red and green algae, *Bangladesh J Bot*, 40 (1) (2011) pp. 41-45.

26 Aziz A, Marine algae of St. Martin's Is., Bangladesh. V. Antithamnionella floccossum (Müller) Whittick, *Bangladesh J Plant Taxon*, 15 (1) (2008) pp. 63-65.

27 Lee R E, *Phycology*, (Cambridge University Press, Cambridge) 1999, pp. 661.

28 Hossain M S, Chowdhury S R & Rashed-Un-Nabi M, Resource mapping of Saint Martin's Island using satellite image and ground observations, *J For Environ*, 5 (2007) 23-36.

29 Majumder S, *Development of value added products from seaweed available in the Bay of Bengal, Bangladesh coast*. MS thesis. Department of Fisheries Technology. Bangladesh Agricultural University, Mymensingh, Bangladesh, 2010.

30 Dennison W C, Effects of light on sea grass photosynthesis, growth and depth distribution, *Aquat Bot*, 27 (1987) 15-26.

31 Neushul M, Foster M S, Coon D A, Woessner J W Hager B W W, An in situ of recruitment, growth and survival of sub tidal marine algae: techniques and preliminary results, *J Phycol*, 12 (1976) 397-408.

32 Cheshire A C, Westphalen G, Weden A, Scriven L J & Rowland B C, Photosynthesis and respiration of phaeophycean-dominated macro algal communities in summer and winter, *Aquat Bot*, 55 (1996) 159-170.

33 Zafar M, *Seaweed culture (Hypnea* sp.*) in Bangladesh-Seaweed Culture Manual-1*. Institute of Marine Science and Fisheries, University of Chittagong, Chittagong, Bangladesh, 2007, pp. 14.

34 Islam M M, Khan M S K, Hasan J, Mallick D & Hoq M E, Seaweed *Hypnea* sp. culture in Cox's bazar coast, Bangladesh, *Bangladesh J Zool*, 45 (1) (2017) 37-46.

35 Devenny J S & Volse L A, Effects of sediments on the development of *Macrocystis pyrifra* gametophytes, *Mar Biol*, 48 (1978) 343-384.

36 Round F E, *The Biology of the Algae*, (Edward Arnold Publisher, Ltd, UK), 1970, pp. 269.

37 FAO/NACA, Regional Study and Workshop on the Taxonomy, Ecology and Processing of Economically Important Red Seaweeds (NACA Environment and Aquaculture Development Series No. 3.), Network of Aquaculture Centres in Asia-Pacific, Bangkok, Thailand, 1996, pp. 151-161.