Bangladesh J. Plant Taxon. **29**(1): 13-29, 2022 (June) DOI: https://doi.org/10.3329/bjpt.v29i1.60446
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SPECIES DIVERSITY, DISTRIBUTION AND STANDING BIOMASS OF SUBLITTORAL SEAWEEDS OF THE ST. MARTIN'S ISLAND, BANGLADESH

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Keywords: Species diversity; distribution; standing biomass; Sublittoral Seaweeds; St. Martin's Island; Bangladesh.

Abstract

Substantial works carried out for over nearly fifty years contributed around 200 taxa under 84 genera along Bangladesh coast specially the St. Martin's Island (SMI) when only intertidal and knee to waist deep seaweeds were collected. Sub-littoral seaweed diversity, their distribution and standing biomass along the coast of the SMI with the assistance of Bangladesh Navy using underwater gears, still photography and videography up to a depth of 15 m, were first studied during March and April 2013. It revealed a total of 40 seaweed taxa of which 16 were browns,12 reds and 12 greens including two new variety *Caulerpa chemnitzia* var. *irregulare* Aziz *et* Alfasane and *C. sertularioides* var. *robusta* Aziz *et* Alfasane. Total taxa were low compared to 1990's and early 2000's affected by human activities and that some smaller forms were washed away by current and waves during collections. Depth profile showed occurrence of a total of 31 (77%) taxa within 1 m and 34 (85%) in the next 1 m (within 2 m) have been considered as highly productive zone; 27 (67%) taxa in the next 1 m (3rd 1m) depth have been considered as the medium productive zone. The lower productivity in the 3rd m depth measured was due to low light (only 16% of surface light 1350 $\mu Em^{-2}s^{-1}$), high Secchi Depth and TDS, all indicating limited light intensity. The number of organisms at 10 m depth decreased to 17 (42%) taxa and at 15 m depth only 4 (10%) taxa were present. The 10 to 15 m depth studied have been considered as low productive zone for March and April environment. The 4 taxa at 15 m were represented by *Peyssonnelia polymorpha*, *Caulerpa taxifolia*, *Halimeda discoidea* and *Dictyota atomaria* and considered as highly adaptive seaweeds. Of these *P. polymorpha* in particular could grow on bare boulders of upper intertidal zone under direct sunlight during lowest tide. The average wet biomass in March and April was 55 g m^{-2} and 902 g m^{-2}, respectively where browns had highest (291.00 g m^{-2}) followed by greens (118.6 g m^{-2}) and reds (45.10 g m^{-2}). Highest average biomass was at location D (696 g m^{-2}) followed by B (179.90 g m^{-2}), A (175.70 g m^{-2}) and C (74.20 g m^{-2}). Total standing sublittoral wet biomass around the SMI was estimated to be 148.50 metric ton for each month based on collections from a total of 50 sites and contribute mostly by *Caulerpa chemnitzia* var. *irregulare* Aziz *et* Alfasane, *C. sertularioides* var, *robusta* Aziz *et* Alfasane, *C. furgusonii*, *Caulerpa taxifolia* and *Asparagopsis taxiformis.* Higher Shannon-Weiner Index of diversity (H') occurred in March at Zone C (3.152) followed by A (2.778), D (2.284), E (1.95) and a minimum at Zone B (1.53). In contrast, Shannon-Weiner Index of diversity (H') showed the higher values at Zone F (2.60) followed by C (1.87), B (1.47), D (1.21) and Zone A showed minimum value (<1). Green seaweed diversity was higher among the classes. The Jaccard similarity index showed slightly higher percentage between Zone A and C (28%) than between Zone C and D (27%) and their intersecting numbers were found to be eight.

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Introduction

Bangladesh has a good number of islands along the south coast facing of Bay of Bengal of which St. Martin’s Island (SMI) occurs in the south-east Coast in the Cox’s Bazar district being surrounded by rocks and boulders in the north-west area extending around Cheradia and up to north (east coast) of Modhapara in addition to corals supporting growth of seaweeds (Islam 1976). In 1980, a large number of samples were collected during scientific expedition to the Island (Islam and Aziz 1982, 1987) along the coasts. Subsequent seaweed collections made from the island were from intertidal zone of the SMI and studies carried out and published by Islam and Aziz and their pupils are available in the list of references of taxa published in Ahmed *et al.* (2008, 2009) and Aziz *et al.* (2015, 2020) where so far as many as 207 seaweed taxa under 82 genera have been included of them two varieties are new to science (*Caulerpa chemnitzia* var. *irregulare* Aziz *et* Alfasane and *C. sertularioides* var, *robusta* Aziz *et* Alfasane, both occurred as common at SMI. However, sub-littoral seaweed studies were limited due to lack of scuba diving gears and facilities. The first author took initiative and Bangladesh Naval authorities provided a ship for seaweed exploration at St. Martin’s Island Bangladesh in March and April 2013. The study aimed at the determining sub-littoral seaweed species diversity, their depth profile and biomass and factors affecting growth and distribution in the St. Martin’s Island, Bangladesh. Several investigations on sub-littoral algae especially deep-water seaweeds were made from different bio-geographical regions (Ali *et al*., 2017; Pereira and Almeida, 2014; Satheesh and Wesley, 2012; Petsut *et al*., 2012; Thakur *et al*., 2008; Rath and Adhikary, 2006; Sansón *et al*., 2002; Norris and Olsen, 1991; Chennubhotla *et al*., 1988; Shepherd and Wormersely, 1970; Dellow, 1954). The taxonomic part of sub-littoral seaweed flora of the St. Martin’s Island, Bangladesh has been published recently (Aziz *et al*., 2015, 2020). The present paper deals with first of its kind, the sub-littoral seaweed species diversity, their depth profile, biomass and factors affecting growth in the St. Martin’s Island, Bangladesh.

Materials and Methods

St. Martin’s Island (Narikeldia) is a tiny ($8.5\ km^{-2}$) dumb-bell shaped island in the extreme southeast of Bangladesh at $20^{\circ}\ 34'\ 26''$ an d $20^{\circ}\ 38'\ 10''$ N and $92^{\circ}\ 18'\ 51''$ and $92^{\circ}\ 20'\ 17''$ E (Fig 1). The Island is surrounded by stones and boulders except the extreme north-east of Narikeldia, where Launch Ghat is situated. Geologist termed it as a ‘coral Island’ while biologists call it a ‘Living Museum’ where a variety of algae and animals inhabit mostly not available along the other part of Bangladesh coast (Aziz, 2001; Aziz *et al*., 2008).The underwater surveys in the SMI were conducted by the first and third authors on two occasions (17-20 March, 2013 and 24-25 April, 2013) taking the help of SCUBA diving team of the Bangladesh Navy having underwater still camera, videography facilities and collecting gears. A total of six locations (A-F) around the island were considered in March and five (A-E) in April (Table 1; Fig. 1). From each location, several samples were collected referred to as sites, using a 1 m Quadrate made of iron rods, Scalper, Chisels and Hammer, and each dive was considered as a site and collected samples as wet samples were kept in polybags. Identifications and distribution of seaweeds and any instructions to divers were done using Videography. Some photographs were taken alive and some from herbaria, while small seaweeds were photographed under a microscope. Fresh weight of whole seaweeds of each site was measured by top loading balance in the field, and in the laboratory by Electronic balance (KERN EG, Germany). Statistical analysis was done using MINITAB 14 software. Several physical and chemical factors were determined: pH by portable Hanna pH meter, Conductivity by ‘*Aqua*’ conductivity meter, Total dissolved solids (TDS) by Hanna Instrument, salinity by refractometer, compensation depth by Secchi disc, light intensity at various depths by Li-Cor, USA and light meter using under water probe. The seaweeds were preserved in two forms, adding formaldehyde and also sample of a species were pressed on to herbarium sheets, archived at National Prof. AKM Nurul Islam Phycology, Limnology and Hydrobiology Laboratory, Department of Botany, University of Dhaka. Five samples from each location were considered as replicates. Seaweeds from near the coast to various depths towards the sea were collected, from a total of 50 sites. At each site depth, GPS position, photography and general observations were recorded. Map of the SMI with six locations and a total of 50 sites are shown elsewhere (Fig. 1; Aziz *et al.*, 2015).

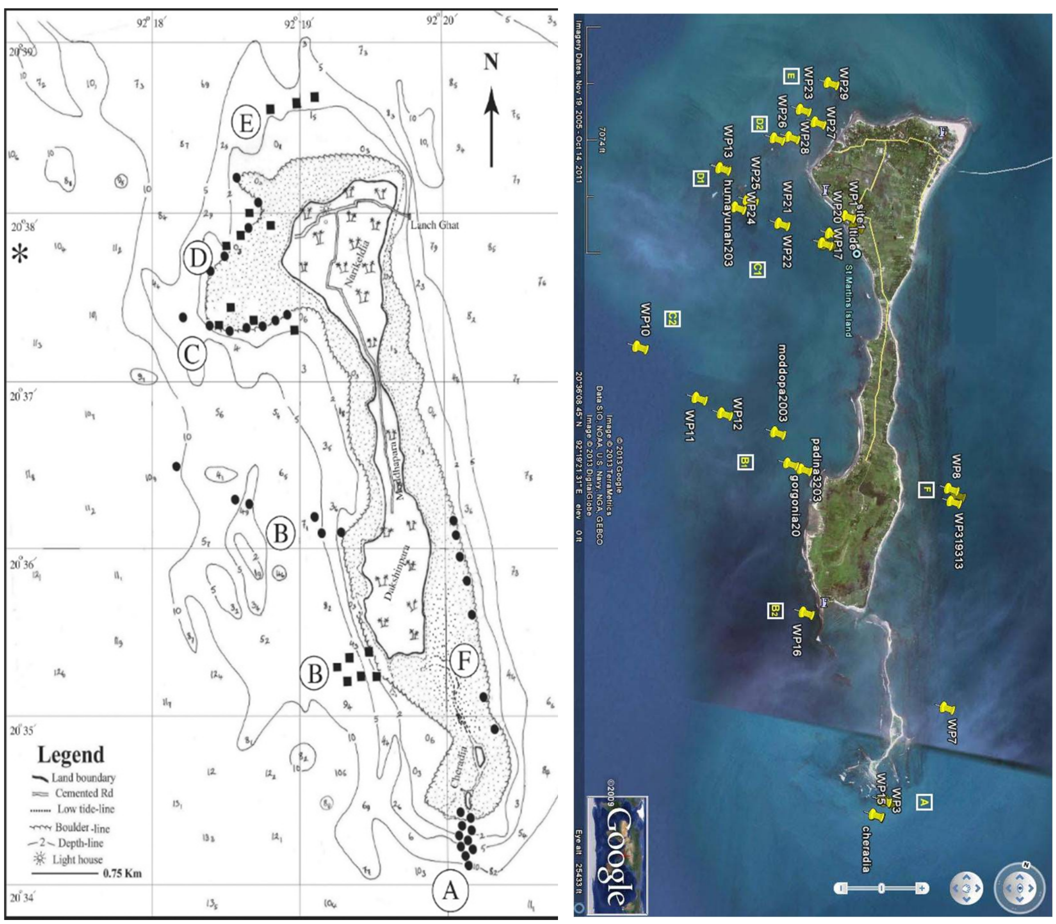

Fig. 1. St. Martin's Island showing locations of sublittoral seaweed collections made on March (●) and April (■) 2013. Boulder-line and depth profile (in meter) around the island and further during low tide is also shown. A survey was done at 15 m depth by video communication system (upper left * indicating 15 m depth, right-GPS map of sampling locations).

Table 1. Collection date, locations and number of samples or sites explored with geographic position of each location (Fig. 1).

Date of collections	Locations	No. of samples or sites	Geographic positions (Lat. & Long).
18-3-13	**A** (South of Cheradia)	10	20º 34′ 08″ - 20° 34′ 27″ N 92° 20′ 05″ - 92° 20′ 10″ E
20-3-13	**B** (North west of Dakshinpara)	5	20° 36′ 06″ - 20° 36′ 30″ N 92° 18′ 10″ - 92° 19′ 17″ E
24-4-13	**B** (South west of Dakshinpara)	6	20° 35′ 13″ - 20° 35′ 27″ N 92° 19′ 16″ - 92° 19′ 32″ E
17-3-13	**C** (West of Coast Guard office)	7	20° 37′ 18″ - 20° 37′ 25″ N 92° 18′ 13″ - 92° 18′ 58″ E
25-4-13	**C** (West of Coral view guest house)	4	20° 37′ 21″ - 20° 37′ 29″ N 92° 18′ 29″ - 92° 18′ 58″ E
20-3-13	**D** (West of Light house)	5	20° 37′ 41″ - 20° 38′ 14″ N 92° 18′ 24″ - 92° 18′42″ E
25-4-13	**D** (West of Light house)	3	20° 37′ 51″ - 20° 38′ 00″ N 92° 18′ 32″ - 92° 18′ 50″ E
25-4-13	**E** (North of Light house)	3	20° 38′ 38″ - 20° 38′42″ N 92° 18′ 50″ - 92° 19′06″ E
19-3-13	**F** (East of Dakshinpara)	7	20° 34′ 57″ - 20° 36′ 10″ N 92° 20′ 04″ - 92° 20′ 20″ E

Results and Discussion

Several physical and chemical factors showed (Table 2, Fig. 2) that higher Secchi depth were observed at Locations A and C followed by B and D in March. On the other hand minimum Secchi depth was measured in April. Different light intensities at different depth of sea water is in agreement with the higher intensity and production of seaweeds at different depths and locations in March (Fig. 2 and Tables 3-4). Sublittoral seaweeds collected from various depths and localities around the SMI were counted and wet wt., length and breadth of plants and plant parts were measured. The values were used to calculate the relative abundance and biomass of 40 taxa of six locations in between months of March and April 2013. The recorded physico-chemical parameters namely, Secchi depth, Light intensity, pH, Salinity, Conductivity and TDS were ranged from 0.95-2.52m, 300-900 $\mu Em^{-2}s^{-1}$, 7.3-7.9, 34-35‰, 42.5-43.3 µS/cm and 11-28.2 mg l^{-1}, respectively during the study period. Physical and chemical parameters recorded show that Secchi Depth (SD) was relatively high 2.52 at Location A that directly faces the open sea, the Bay of Bengal that might cause high turbulence compared to relatively low at Locations B and C, about 3 km North having rocky bottom (Fig. 1) were 1.0-1.9 and 0.95 – 2.42, respectively (Table 2). The SD increased proportionately to light and TDS which in the location corresponds to Secchi Depth. The light quantity (Fig. 2) likewise corresponds to SD and TDS. The SD increased proportionate to light and TDS. The TDS in the location corresponds to Secchi depth. The loght quantity (Fig. 2) likewise corresponds to SD and TDS. Below 900 $\mu Em^{-2}s^{-1}$ (66%) in the surface water decreased to 328 $\mu Em^{-2}s^{-1}$ (21%) at 2 m and 278 $\mu Em^{-2}s^{-1}$ (278 E $\mu Em^{-2}s^{-1}$ at 3 m, so good relationship with Secchi depth and pH being higher in the surface than at 5m. So, the low TDS, and STD directly correspond to light quantity, so does the seaweed biomass and number. Salinity and Conductivity do not vary around the SMI. A surface light of 1350 $\mu Em^{-2}s^{-1}$ reduced to 577 (47%), 329 (24%) and 278 (16%) at 1, 2 and 3 m depths (could not measure from the surface due 3 m cord length).

Rath and Adhikary (2006) were reported 21 species of macro-algae (seaweeds) from the coastal region of Orissa state. Of these 9 species belong to Chlorophyta, 10 to Rhodophyta and 2 to Phaeophyta. They also observed abundance of seaweeds during October to February in the coast of Orissa when the air temperature was moderate between 20 to 32°C. Their research findings also showed in summer (April to June), when the air temperature was invariably in the range of 35 to 45°C, the quantity of all seaweeds was decreased. They also showed Rhodophyta was dominant followed by Chlorophyta which is a common phenomenon in the tropical distributional pattern of seaweeds in this region.

Table 2. Physical and chemical parameters in summer (March to April) at three locations of St. Martin's Island, Bangladesh. *Light intensities ($\mu Em^{-2}s^{-1}$) at two Secchi depths are shown in parentheses.

Parameters	Locations		
March	A	B	C
Secchi depth (m)	2.52	1.0-1.90	0.95-2.42 2.50 (180*) 3.00 (159*)
pH	7.9 (Sarface) 7.3 (5 m depth)	7.8 (surface) 7.6 (5 m depth)	7.30
Salinity (‰)	34.00	34	35.00
Conductivity (µS/cm)	43.00	43.30	42.50
TDS (mg/l)	27.60	11	28.20

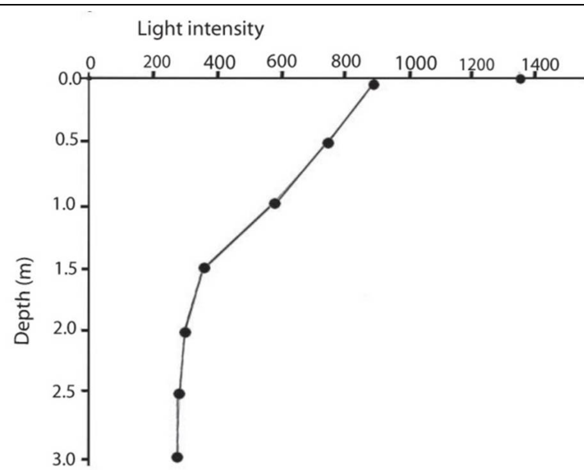

Fig. 2. Light profile in sea water on 17 March 2013, south of Cheradia, St. Martin's Island.

At Cheradia (location A) a total of 13 taxa have been recorded, the total number of the organisms were 252 having a total weight of 22.837 kgm^{-2} in 10 sites studied on 18-3-2013. The average overall number of seaweeds was 1.938 m^{-2} at Cheradia (Table 4). Individually highes

Table 3. Number of seaweeds at different localities in the month of March and April. Average number of each taxon m^{-2} for two months and Monthly Overall number of seaweeds m^{-2} at each location are also shown. Results are the means of 'number of sites' at each locality.

	Localities										
Seaweed taxa	A(Mar) 10 sites	A(Apr) no sites	B(Mar) 5 sites	B(Apr) 6sites	C(Mar) 7 sites	C(Apr) 4 sites	D(Mar) 5 sites	D(Apr) 3 sites	E(Apr) 3 sites	F(Mar) 7 sites	Average Number
Rhodophyceae											
Asparagopsis taxiformis	12	-	-	-	1	-	-	-	-	-	0.670 ±0.750
Dasya corymbifera	-	-	-	-	1	-	-	-	-	-	0.140
D. pedicellata	-	-	-	-	1	-	-	-	-	-	0.140
Galaxura fastigiata	-	-	-	-	-	-	-	-	2	-	0.660
Gracilaria spinuligera	-	-	-	-	1	-	-	-	-	-	0.140
Halymenia floridana	-	-	-	1	-	-	-	-	-	-	0.160
Halymenia floresia	-	-	-	-	-	1	-	-	-	-	0.250
Hypnea boergesenii	-	-	-	-	20	1	-	-	1	-	1.143 ±1.479
Jania ungulata	19	-	-	-	1	1	-	-	1	4	0.638 ±0.723
Neurymenia fraxinifolia	-	-	-	-	8	-	-	-	-	-	1.140
Peyssonelia polymorpha	4	-	-	-	-	-	-	-	-	-	0.400
Vanvoorstia coccinea	-	-	-	-	-	-	-	-	-	4	0.570
Total number	1.167 ±0.751	-	-	0.16	0.814 ±1.017	0.25 ±0.00	-	-	0.440 ±0.191	0.571 ±0.00	0.504 ±0.367

Table 3 contd.

	Localities										
Seaweed taxa	A(Mar) 10 sites	A(Apr) no sites	B(Mar) 5 sites	B(Apr) 6sites	C(Mar) 7 sites	C(Apr) 4 sites	D(Mar) 5 sites	D(Apr) 3 sites	E(Apr) 3 sites	F(Mar) 7 sites	Average Number
Chlorophyceae											
Avrainvillea amadelpha	-	-	-	-	1	-	-	-	-	-	0.140
Caulerpa furgusoni	31	-	-	-	-	-	-	-	-	1	1.620 ±2.090
Caulerpa chemnitzia var. *irregulare* Aziz & Alfasane	42	-	-	-	1	-	-	-	-	-	1.620 ±2.090
C. racemosa var. *clavifera*	-	-	-	-	2	-	-	-	-	2	0.280
C. racemosa var. *occidentalis*	-	-	-	-	2	-	-	-	-	2	0.280
Caulerpa sertularioides var. *robusta* Aziz & Alfasane	-	-	6	-	-	-	4	-	-	-	1.000 ±0.283
C. taxifolia	16	-	-	-	30	8	20	-	-	6	2.731 ±1.780
Cladophora prolifera	-	-	-	-	3	-	-	-	-	-	0.420
Codium geppei	-	-	-	-	-	-	-	-	-	1	0.140
Halimeda discoidea	-	-	12	9	47	1	2	3	35	23	2.731 ±1.777
H. incrassata	69	-	10	-	10	24	4	-	-	33	3.640 ±2.570
H. opuntia	27	-	-	-		22	-	-	-	20	3.686 ±1.573
Total number	3.700 ±2.016	-	1.867 ±0.611	1.50	1.710 ±2.461	3.44 ±2.77	1.500 ±1.677	1.00	11.66	1.561 ±1.791	1.524 ±1.365

Table 3 contd.

Seaweed taxa	A(Mar) 10 sites	A(Apr) no sites	B(Mar) 5 sites	B(Apr) 6sites	C(Mar) 7 sites	C(Apr) 4 sites	D(Mar) 5 sites	D(Apr) 3 sites	E(Apr) 3 sites	F(Mar) 7 sites	Average Number
Phaeophyceae											
Chnoospora implexa	-	-	-	-	1	-	-	-	3	2	0.475 ±0.460
Dictyota atomaria	-	-	-	-	-	-	-	-	-	8	1.140
Dictyopteris australis	-	-	-	15	2	5	6	19	13	-	2.940 ±2.430
P. gymnospora	-	-	9	-	-	-	-	-	-	-	1.800
Padina tenuis	-	-	-	-	-	-	-	-	-	4	0.570
P. pavonica	-	-	-	-	9	-	-	-	-	-	1.280
Lobophora heteracea	15	-	-	-	-	1	-	-	-	-	0.875 ±0.884
Spatoglossum asperum	-	-	-	25	3	-	32	-	-	-	3.660 ±3.020
S. variabile	-	-	-	-	-	12	-	32	20	-	6.770 ±3.830
Sargassum coriifolium										5	0.710
S. olygocystum	1	-	-	-	-	-	-	-	-	-	0.100
S. swartzii					6						0.850
S. (?) *pallidum*	7	-	-	-	-	-	-	-	-	-	0.700
S. flavicans	8	-	-	-	-	-	-	-	-	-	0.800
S. tenerrimum	-	-	-	-	-	-	12	-	-	-	2.400
S. cracifolium	1	-	-	-	-	-	-	-	-	-	0.100
Total number	0.640 ±0.581	-	1.80	3.330 ±1.174	0.594 ±0.467	1.500 ±1.392	3.33 ±2.72	5.773 ±1.261	4.00 ±2.84	0.675 ±0.358	1.573 ±1.711
Grant Total number	252	0.00	37	50	147	76	80	54	75	115	-
Average Monthly number	1.938 ±1.925	0.0	1.720 ±0.522	1.700 ±1.693	1.257 ±1.861	1.900 ±2.237	2.286 ±2.200	6.000 ±4.840	3.570 ±4.310	1.172 ±1.407	1.257 ±1.400
Average Overall number	1.938 ± 1.925		1.710 ± 1.181		1.505 ± 1.995		3.40 ± 3.41		-	-	-

Table 4. Biomass of seaweeds (g m^{-2}) at different localities each having several sites in the month of March and April. Average biomass of each taxon and Average Monthly Overall biomass of seaweeds at each location are also shown. Results are the means of 'number of sites' at each locality.

	Localities										
Seaweed taxa	A(Mar) 10 sites	A(Apr) no sites	B(Mar) 5 sites	B(Apr) 6sites	C(Mar) 7 sites	C(Apr) 4 sites	D(Mar) 5 sites	D(Apr) 3 sites	E(Apr) 3 sites	F(Mar) 7 sites	Average biomass
Rhodophyceae											
Asparagopsis taxiformis	2840	-	-	-	160	-	-	-	-	-	153.00 ±185.00
Dasya corymbifera	-	-	-	-	-	-	-	-	-	-	-
D. pedicellata	-	-	-	-	-	-	-	-	-	-	-
Galaxura fastigiata	-	-	-	-	-	-	-	-	400	-	133.33
Gracilaria spinuligera	-	-	-	-	150	-	-	-	-	-	2.14
Halymenia floridana	-	-	-	175	-	-	-	-	-	-	29.16
H. floresia	-	-	-	-	-	30	-	-	-	-	7.50
Hypnea boergesenii	-	-	-	-	330	20	-	-	200	-	39.60 ±31.50
Jania ungulata	200	-	-	-	20	10	-	-	10	160	10.31 ±10.20
Neurymenia fraxinifolia	-	-	-	-	500	-	-	-	-	-	71.42
Peyssonelia polymorpha	27	-	-	-	-	-	-	-	-	-	2.70
Vanvoorstia coccinea	-	-	-	-	-	-	-	-	-	50	7.14
Total biomass	102.20 ±157.70	-	-	29.16	29.30 ±29.90	5.00 ±2.50	-	-	67.80 ±65.00	15.00 ±11.11	45.60 ±55.80

Table 4 contd.

Seaweed taxa	A(Mar) 10 sites	A(Apr) no sites	B(Mar) 5 sites	B(Apr) 6sites	C(Mar) 7 sites	C(Apr) 4 sites	D(Mar) 5 sites	D(Apr) 3 sites	E(Apr) 3 sites	F(Mar) 7 sites	Average biomass
Chlorophyceae											
Avrainvillea amadelpha	-	-	-	-	15	-	-	-	-	-	2.14
Caulerpa furgusoni	8600	-	-	-	-	-	-	-	-	130	439.00 ±595.00
Caulerpa chemnitzia var. *irregulare* Aziz & Alfasane	2610	-	-	-	30	-	-	-	-	-	140.00 ±171.00
C. racemosa var. *clavifera*	-	-	-	-	90	-	-	-	-	175	7.71 ± 7.27
C. racemosa var. *occidentalis*	-	-	-	-	100	-	-	-	-	180	20.00 ±8.08
Caulerpa sertularioides var. *robusta* Aziz & Alfasane	-	-	550	-	-	-	1000	-	-	-	139.30 ±85.90
C. taxifolia	810	-	-	-	2310	200	3000	-	-	700	232.00 ±234.00
Cladophora prolifera	-	-	-	-	150	-	-	-	-	-	21.42
Codium geppei	-	-	-	-	-	-	-	-	-	420	60.00
Halimeda discoidea	-	-	1000	332	1655	40	70	140	2400	2400	213.20 ±266.10
H. incrassata	4010	-	120	-	250	540	10	-	-	1720	140.60 ±156.00
H. opuntia	690	-	-	-	-	460	-	-	-	425	81.60 ±9.20
Total biomass	334 ±324	-	111.30 ±88.00	55.33	82.10 ±127.00	77.50 ±57.80	204 ±279	46.66	800	109.80 ±119.70	118.60 ±122.80

Table 4 contd.

Seaweed taxa	Localities: A(Mar) 10 sites	A(Apr) no sites	B(Mar) 5 sites	B(Apr) 6sites	C(Mar) 7 sites	C(Apr) 4 sites	D(Mar) 5 sites	D(Apr) 3 sites	E(Apr) 3 sites	F(Mar) 7 sites	Average biomass
Pheaophyceae											
Chnoospora implexa	-	-	-	-	8	-	-	-	40	20	5.78 ±6.60
Dictyota atomaria	-	-	-	-	-	-	-	-	-	2590	370.00
Dictyopteris australis	-	-	-	2405	20	610	300	3000	1400	-	347.00 ±369.00
Padina gymnospora	-	-	130	-	-	-	-	-	-	-	26.00
P. tenuis	-	-	-	-	-	-	-	-	-	530	75.71
P. pavonica	-	-	-	-	150	-	-	-	-	-	21.42
Lobophora heteracea	460	-	-	-	-	60	-	-	-	-	30.50 ±21.90
Spatoglossum asperum	-	-	-	5500	220	-	11900	-	-	-	1109 ±1186
S. variabile	-	-	-	-	-	2390	-	4980	9190	-	1774 ±1237
Sargassum coriifolium	-	-	-	-	-	-	-	-	-	350	50.00
S. olygocystum	460	-	-	-	-	-	-	-	-	-	46.00
S. swartzii					700						100.00
S. (?) *pallidum*	800	-	-	-	-	-	-	-	-	-	80.00
S. flavicans	1200	-	-	-	-	-	-	-	-	-	100.00
S. tenerrimum	-	-	-	-	-	-	5000	-	-		500.00
S. cracifolium	130	-	-	-	-	-	-	-	-	-	13.00
Total biomass	61.00 ±40.60	-	26.00	659 ±365	31.40 ±40.40	255 ±304	1147 ±1167	1330 ±467	1181 ±1646	124.60 ±166.30	291.00 ± 488
Grand Total biomass	22,837	0.00	1800	8412	6708	4360	21280	8120	13640	9850	-
Average Monthly biomass	175.70 ±238.90	0.00	111.70 ±78.30	248 ± 358	54.80 ±88.40	109.00 ±181.30	608 ±864	902 ±811	649 ±1104	79.10 ±103.50	163.6 ±358.6
Average Overall biomass	175.70 ± 238.90		179.70 ± 257.00		74.20 ± 128.80		696 ± 815		-	-	-

number was recorded for *Halimeda opuntia/incrassata* followed by *Caulerpa peltata*, *C. cactoides*, *Jania ungulata*, etc. On the basis of weight the average overall biomass was 175.70 gm^{-2} (Table 4). Individually highest biomass was recorded for *Sargassum* spp. followed by *Caulerpa cactoides*, *Caulerpa taxifolia,* etc. Of the three groups greens had highest biomasss followed by reds and browns (Table 4).

At North West of Dakshinpara (location B) a total of 4 taxa have been recorded, the total number of seaweeds were 37 having a total weight of 1.800 kgm^{-2} in 5 sites in March. In April the total biomass was 8.412 kgm^{-2} (Tables 3-4). The average monthly number of seaweeds was 1.720 m^{-2}. Individually highest number was recorded for *Halimeda discoidea* followed by, *Padina gymnospora* and *Caulerpa sertularioides* var. *brevipes*, *Halimeda opuntia/incrassata*, etc. (Table 3). Individually highest biomass was recorded for *Halimeda discoidea* followed by *Halimeda incrassata*, *Padina gymnospora* etc. (Table 4). On the basis of weight the average monthly biomass was 111.7 g m^{-2} (Table 4). Of the three groups greens had highest biomass followed by browns, reds were absent in the location.

At west of Coast Guard Office (location C) a total of 19 taxa have been recorded, the total number of seaweeds were 147 having a total weight of 6.708 kg in 7 sites in March (Tables 3-4). The average overall number of seaweeds was 1.257 m^{-2} (Table 3). In April the total biomass was 4.36 kgm^{-2}. Individually highest number was recorded for *Halimeda discoidea* followed by *Caulerpa taxifolia*, *Neurymenia fraxnifolia*, *Hypnea boergesenii*, *Asparagopsis taxiformis* etc. (Table 3). On the basis of weight the average monthly biomass was 54.80 g m^{-2} (Table 4). Individually highest biomass was recorded for *Caulerpa taxifolia* followed by *Halimeda discoidea*, *Sargassum swatzii*, *Spatoglossum asperum* followed by *Neurymenia fraxnifolia*, *Hypnea musciformis*, *Halimeda incrassata*, etc. (Table 4). Of the three groups greens had highest biomass followed by browns and reds.

At West of Light House (location D) a total of 7 taxa have been recorded, the total number of seaweeds were 80 having a total weight of 21.280 kg m^{-2} in 5 sites in March (Tables 3-4). Individually highest number was recorded for *Spatoglossum asperum* followed by *Caulerpa taxifolia*, *Caulerpa sertularioides* var. *brevipes*, *Sargassum tenerrimum* and *Dictyopteris australis*. The average monthly number of seaweeds was 2.286 m^{-2}. Reds were absent (Table 3). On the basis of weight the average overall biomass was 608 gm^{-2} in March and 902 gm^{-2} in April (Table 4). Individually highest biomass was recorded for *Spatoglossum asperum* followed by *Sargassum tenerrimum* and *Caulerpa taxifolia* (Table 4). Of the three groups browns had highest biomass followed by greens.

At South West of Dakshinpara (location B) a total of 4 taxa have been recorded, the total number of seaweeds were 50 having a total weight of 8.412 kgm^{-2} in 6 sites in March (Tables 3-4). Individually highest number was recorded for *Spatoglossum asperum* followed by *Dictyopteris australis* and *Halimeda discoidea* (Table 3). The monthly number of seaweeds was 1.700 m^{-2} at East of Dakshinpara (Location F). Individually highest biomass was recorded for *Spatoglossum asperum* followed by *Dictyopteris australis*, *Halimeda discoidea,* etc. (Table 4). On the basis of weight the average monthly biomass was 248 g m^{-2} (Table 4). Of the three groups browns had highest biomass followed by greens and reds.

At West of Coral view guest house (location C) a total of 10 taxa have been recorded, the total number of seaweeds were 76 having a total weight of 4.360 kgm^{-2} in 3 sites in April (Tables 3-4). The average monthly number of seaweeds was 1.900 m^{-2} (Table 3). Individually highest number was recorded for *Halimeda opuntia/incrassata* followed by *Caulerpa taxifolia* (Table 3). The average overall biomass was 109.00 g m^{-2} (Table 4). Individually highest biomass was recorded for *Halimeda opuntia/incrassata* followed by *Spatoglossum variabile*, *Dictyopteris australis, C. taxifolia*, etc. (Table 4). Of the three groups browns had highest followed by greens and reds.

At West of light house (location D) a total of 3 taxa have been recorded, the total number of seaweeds were 54 having a total weight of 8.120 kgm^{-2} in 3 sites in April (Tables 3-4). Individually highest number was recorded for *Spatoglossum variabile* followed by *Dictyopteris australis* and *Halimeda discoidea* (Table 3). The average monthly number of seaweeds was 6.000 m^{-2} at location D (Table 3). Individually highest biomass was recorded for *Spatoglossum variabile* followed by *Dictyopteris australis*, *Halimeda discoidea* (Table 4). On the basis of weight the average monthly biomass was 902 g m^{-2} (Table 4). Of the three groups browns had highest followed by greens, reds were absent.

At North of light house (location E) a total of 7 taxa have been recorded, the total number of seaweeds were 75 having a total weight of 13.640 kgm^{-2} in 3 sites in April. Individually highest number was recorded for *Halimeda discoidea* followed by *Spatoglossum variabile*, *Dictyopteris australis*, etc. (Table 3).The average overall number of seaweeds was 3.570 m^{-2} at North of light house (Table 3). Individually highest biomass was recorded for *Spatoglossum variabile* followed by *Halimeda discoidea, Dictyopteris australis*, *Galaxura fastigiata*, etc. (Table 4).On the basis of weight the average monthly biomass was 649 gm^{-2} (Table 4). Of the three groups browns had highest followed by greens and reds.

At East of Dakshinpara (location F) a total of 12 taxa have been recorded, the total number of seaweeds were 115 having a total weight of 9.850 kg m^{-2} in 7 sites in March (Tables 3-4). Individually highest number was recorded for *Halimeda incrassata* followed by *H. discoidea*, *H. opuntia* (Table 3). The average monthly number of seaweeds was 1.172 m^{-2} at Location F (Table 3). On the basis of weight the average monthly biomass was 79.10 g m^{-2} (Table 4). Individually highest biomass was recorded for *Dictyota atomaria*, *Halimeda discoidea* followed by *H. opuntia/incrassata*, *Padina tenuis, Caulerpa taxifolia,* etc. (Table 4). Of the three groups greens had highest biomass followed by browns and reds.

In the present investigation it has been found that seaweeds occur from 0.2 to 15 m depth (may be further) of the SMI. It appeared that average overall number of seaweed taxa in the Island varies from 1.505 to 3.40 m^{-2} (Table 3). The highest average overall number was found at locations D, followed by A, B and C. The average monthly number for locations E (sheltered zone) and F were 3.570 and 1.172 m^{-2}, respectively (Table 3). A total of 40 taxa were recorded from the six locations (Table 3). The total number of seaweed taxa recorded from sublittoral zones appears to be small compared to the taxa reported so far from the SMI, Bangladesh. This might be due to harsh weather in late spring and early summer months (February in the period of optimum growth); microscopic forms were not considered; smaller delicate seaweeds under turbulent water may have been washed out and microscopic epiphytes were avoided (*Dsaya*, microscopic form came into notice as attached to *Avrainvillea amdelpha*). However, the dominant taxa in the SMI in terms of number were spp. of *Spatoglossum*, *Halimeda opuntia*/*incrassata*, *Dictyopteris australis*, *Caulerpa taxifolia, H. discoidea, Caulerpa chemnitzia* var. *irregulare* Aziz & Alfasane and spp. of *Sargassum* (Tables 3-4). Floristic composition in the St. Martin’s Island was more or less similar to the Kerala coastline (Chennubhotla *et al.*, 1988). They recorded 35 seaweed taxa from 0.00 to 0.5 m depth covering nearly 580 km. Some taxa like *Caulerpa chemnitzia* var. *irregulare* Aziz & Alfasane, *C. sertularioides, Caulerpa taxifolia, Spatoglossum asperum* and *Padina gymnospora found in* Kerala coastline were also found in the SMI.

Occurrence of seaweed taxa in different localities varied. Out of 6 locations *Caulerpa taxifolia, Halimeda discoidea* and *H. incrassata* were present in 5 locations where as *Dictyopteris australis* and *Jania ungulata* were present in 4 locations (Table 3). Browns and greens were found in all the six localities but reds were present in only six occasions. The total biomass of browns was vary high followed by greens and reds. Average number of seaweeds m^{-2} was 1.573, 1.524 and 0.504 for browns, greens and reds, respectively.

The average monthly biomass in the present study varied from 54.80 to 902 g m^{-2} (Table 4). The average overall biomass showed almost similar pattern being highest in location D (696 gm^{-2}) followed by B (179.90 gm^{-2}), A(175.70 gm^{-2}) and C(74.20 gm^{-2}). However, average biomass contributed by browns was highest (291.00 gm^{-2}) followed by greens (118.6 gm^{-2}) and reds (45.10 gm^{-2}). The total standing sublittoral biomass around the SMI was 148,50 metric ton for both the months separately.

The average overall biomass was highest at location D followed by B, A and C. If the average monthly biomass of March is compared with April, the later had highest biomass and largely contributed by large brown seaweeds because of strong thalli (Table 4). Greens seaweeds however were higher in March compared to April, which might be due to their delicate nature. Pereira and Almeida (2014) had compiled the seaweeds list of the Goa coast-on the basis of fresh collections of which 145 specimens comprising of 64 species of reds, 41 species of greens, and 40 brown algae, the result varied largely with present study where browns had highest followed by greens and reds. They also reported 70 seaweeds species as new records for the Goa coast, in contrast only two varieties of *Caulerpa* namely, *Caulerpa chemnitzia* var. *irregulare* Aziz & Alfasane., *Caulerpa sertularioides* var. *robusta* Aziz & Alfasane were new to science and seven were new records. Nine species of sublittoral and deep-water red and brown algae were also reported from the Canary Islands for the first time (Sansón *et al*, 2002). Dellow (1954) reported 241 seaweeds from the Gulf region, in contrast to 207 in the SMI. A comparison of the seaweeds taxa common to St. Martin's Island, Bangladesh and coasts of India revealed five taxa of Rhodophyceae, fourteen taxa of Chlorophyceae and eleven taxa of Pheophyceae as common (Table 5). Ali *et al*. (2017) were also reported a total of 36 species (16 Phaeophyceae, 12 Rhodophyta, and 8 Chlorophyta) of sublittoral seaweeds from in the coastal waters of Sindh (Pakistan). Total sublittoral seaweed taxa were 40 in the SMI higher than Kerala, India having 13 taxa (Chennubhotla *et al.*, 1988), Kudankulam, India having 15 taxa (Satheesh and Wesley, 2012) and Port Okha, India having 17 taxa (Thakur *et al.*, 2008) indicating rich seaweed diversity.

Vertical profile of sublittoral seaweeds

Sublittoral seaweeds collected from various depths and six localities around SMI were identified and were plotted as per their depth of occurrence on to the Fig. 3. It appears that of the total 40 taxa as many as 28 taxa were present within 1 m depth, whereas 23 taxa within 2 m and 13 taxa up to 3m. It revealed a total of 40 seaweed taxa of which 16 were browns, 12 reds and 12 greens including two new variety *Caulerpa chemnitzia* var. *irregulare* Aziz *et* Alfasane and *C. sertularioides* var, *robusta* Aziz *et* Alfasane (Aziz and Alfasane, 2020). Total taxa were low compared to 1990's and early 2000's affected by human activities and that some smaller forms were washed away by current and waves during collections. Depth profile showed occurrence of a total of 31 (77%) taxa within 1 m and 34 (85%) in the next 1 m (within 2 m) have been considered as highly productive zone; 27 (67%) taxa in the next 1 m (3rd 1m) depth have been considered as the medium productive zone). The lower productivity in the 3rd m depth measured was due to low light (only 16% of surface light 1350 $\mu Em^{-2}s^{-1}$), high Secchi Depth and TDS, all indicating limited light intensity. The number of organisms at 10 m depth decreased to 17(42%) taxa and at15 m depth only 4(10%) taxa were present. The number of taxa decreased substantially in the deeper areas. However this distribution pattern should be considered carefully for the following reasons: (i) It was not possible to collect samples after every 1m depth of each location, (ii) Representative samples and locations were low (only 5 locations in an Island of 8.5 km^2) and (iii) Possibility of losing small and delicate samples during collections due to waves and current cannot be ruled out.

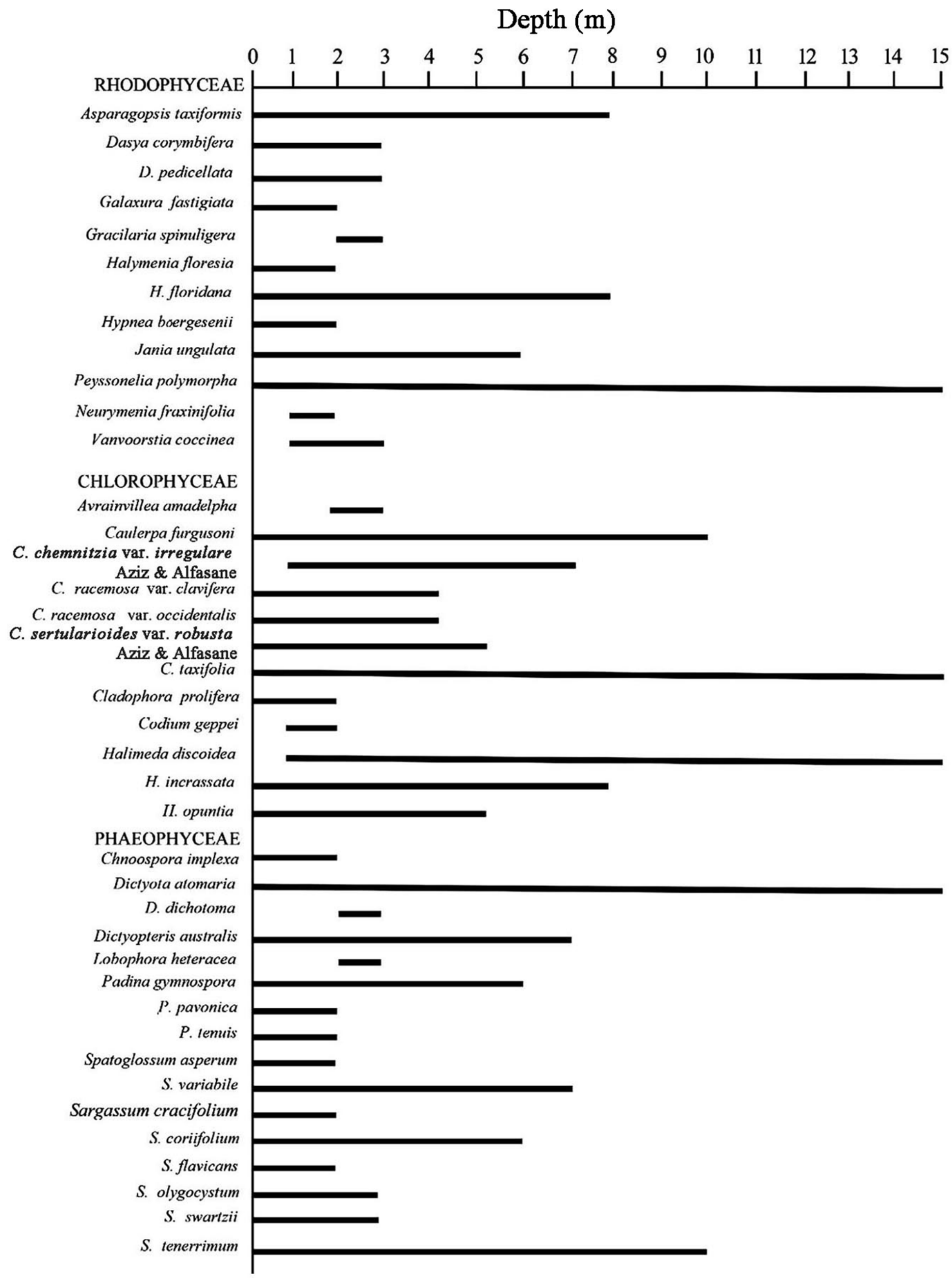

Fig. 3. Depth profile of sublittoral seaweeds of three classes collected from different sites and locations around the SMI during March and April 2013.

Relative occurrence of the taxa within 3 m depth was determined considering their presence in ≥ 8 places as abundant, 4-7 places as common, 2-3 places as few and only on place as rare. The dominant taxa from 0.2 to up to 3.0 m depth were (in a decreasing order): *Caulerpa taxifolia*, *Halimeda discoidea*, *Dictyopteris australis*, *Spatoglossum asperum* followed by *Hypnea musciformis*, *Jania ungulata*, *Peyssonnelia polymorpha*, *Halimeda opuntia*/*incrassata*, *Caulerpa cactoides*, *C. racemosa* var. *brevipes*, var. *clavifera*, *Dictyota atomaria*, spp. of *Padina* and *Galaxura fastigiata*. The rare spp. were *Pocokiella variegata*, *Neurymenia fraxinifolia*, *Vanvoorstia coccinea*, *Codium geppei* and *Avrainvillea amadelpha* (Table 3). Greens and browns appeared to dominant in deeper area though *Peyssonnelia polymorpha* a red alga was found at 15 m depth. Petsut *et al*. (2012) were also investigated species diversity, biomass and distribution pattern of seaweed beds in relation to environmental conditions from January to December 2011 in the Trat peninsula, east coast of Thailand. They reported 26 taxa of marine benthic algae of which 16 species of red marine algae were the most diverse group. They found that *Catenella nipae*, *Gracilaria salicornia*, *Gelidium pusillum*, *Hydropuntia changii*, *Hypnea hamulosa*, *Kyrtutrix maculans*, *Laurencia decumbents*, *Lyngbya majuscula*, *Peyssonnelia rubra* and *Ulva clathrata* were the most abundant. They also found highest number of seaweeds in March (25 species), on the other hand the lowest in June (12 species). They also reported seaweeds biomass had a maximum value in April (59.50 g/m^2 dry weight) and minimum value in July (20.14 g/m^2 dry weight). The 10 to 15 m depth studied have been considered as low productive zone for March and April environment. The 4 taxa at 15 m were represented by *Peyssonnelia polymorpha*, *Caulerpa taxifolia*, *Halimeda discoidea* and *Dictyota atomaria* and considered as highly adaptive seaweeds. Of these *P. polymorpha* in particular could grow on bare boulders of upper intertidal zone under direct sunlight during lowest tide. The average wet biomass in March and April was 55 g m^{-2} and 902 g m^{-2}, respectively where browns had highest (291.00 g m^{-2}) followed by greens (118.6 g m^{-2}) and reds (45.10 g m^{-2}). Highest average biomass was at location D (696 g m^{-2}) followed by B (179.90 g m^{-2}), A (175.70 g m^{-2}) and C (74.20 g m^{-2}). Total standing sublittoral wet biomass around the SMI was estimated to be 148.50 metric ton for each month based on collections from a total of 50 sites and contribute mostly by *Caulerpa chemnitzia* var. *irregulare* Aziz *et* Alfasane, *C. sertularioides* var, *robusta* Aziz *et* Alfasane, *C. furgusonii*, *Caulerpa taxifolia* and *Asparagopsis taxiformis*. Higher Shannon-Weiner Index of diversity (H') occurred in March at Zone C (3.152) followed by A (2.778), D (2.284), E (1.95) and a minimum at Zone B (1.53). In contrast, Shannon-Weiner Index of diversity (H') showed the higher values at Zone F (2.60) followed by C (1.87), B (1.47), D (1.21) and Zone A showed minimum value (<1). Green seaweed diversity was higher among the classes. The Jaccard similarity index showed slightly higher percentage between Zone A and C (28%) than between Zone C and D (27%) and their intersecting numbers were found to be eight.

Acknowledgements

Heartfelt gratitude to the Bangladesh Navy authority for providing the Naval Ship and Scuba Divers with Underwater Photography and Communication Systems to carry out the research in the bottom of the sea. Special thanks to Commander M. Zahid Hossain, (TAS), Psc Co BNS SAIKAT for providing all out help for four days in the sea. Authors are grateful to Mr. Md. Monirul Islam for giving his continuous support to collection of the samples and preparation of the manuscript.

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(Manuscript on 16 January 2021; revised on 23 January 2022)