Spatial and Temporal Profiling of Macroalgal Groups on Shore Platform: A case study from Dwarka

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Abstract Dwarka coast of Gujarat state from India has a stable shore platform. For this study, the shore platform was divided into three sections: i) northern, ii) central and iii) southern. Macroalgae growing on this shore platform were surveyed based on systematic random sampling for three months in sequence (April, June and October, 2013). On this site, total 36 taxa of macroalgae were identified through intensive fieldwork/in situ survey based on Line Intercept Transect and Quadrate based methods. An overall analysis of the field data so far collected reveals that Chlorophyta dominates in the subtidal zone while Ochrophyta (Phaeophyta) dominates in rock pools near the cliff base as their preferred habitats. Rhodophyta showed a seasonal predominance during June. Iyengaria stellata was found in all the three months. The result obtained in this study provides an insight to understand the macroalgae habitat zonation on the shore platform and can be useful to support conservation of this study site as a rich macroalgae habitat of Indian Coast.

Keywords Macroalgae; Spatial and temporal variation; Stages of growth; Shore platform; Dwarka coast

Introduction Marine macroalgae, popularly known as seaweeds, are the most beautiful groups of photosynthetic organisms, which grow under the ocean’s blue water (Sahoo, 2010). They grow in the intertidal and subtidal zones (shallow and deep areas), in the estuaries and backwaters on solid substrates such as rocks, corals, pebbles, shells and even on plant materials (Kumar, et al., 2009). Macroalgae are the ecological base of most of the close-shore tropical and temperate marine ecosystems. Their diversity supports a mass of other taxa, provides essential ecosystem services in the coastal zone, supply food and shelter for thousands of associated plant/animal species and their loss or replacement may lead to substantial negative implications for ecological function and biodiversity (Wernberg, et al., 2011).

The floristic variations in macroagal communities are controlled by several environmental factors, including season, habitat, topography, duration of tidal exposure, tidal amplitude and biotic factors (algal turf, grazing, high concentration of limpets and many others) (Jha, et al., 2009). Macroalgae are economically very important: they are used as food, fodder, fertilizer and also as source of raw materials for industry, production of medicines, cosmetics and others products. Study on seasonal variation of macroalgae in Indian waters specifically in the east and west coasts of peninsular India were carried out by various researchers from the eighteenth century (Gohil and Kundu, 2012; Sahoo, 2010; Jha, et al., 2009; Untawale, et al., 1983; Børghesen, 1935; Iyengar, 1927). M. O. P. Iyengar (1927) was the first phycologist to report marine flora of the Indian coast.

The present study was carried out with the following objectives:

To study spatial variations in different macroalgae groups;
To study temporal variations in different macroalgae groups;
To record stages of growth of different macroalgae taxa with respect to the sampling seasons.
1 Results

1.1 Shore Platform Zones

From the field data, it emerged that the shore platform can be divided into three zones (in East-West direction) based on taxonomic groups of macroalgae (www.algaebase.org) observed. The shore platform can be divided into: i) cliff base part ii) an intertidal mixed zone and iii) a subtidal zone at the seafront. In this study, it is found that Ochrophyta (Phaeophyta) in rock pools (these pools were found in less numbers in the northern section) dominate the cliff base part. The cliff base is followed by a mixed intertidal area, where there is a transition from Ochrophyta (dominant in the intertidal zone) to Chlorophyta (dominant in the subtidal zone). The subtidal zone dominated by Chlorophyta is found at the seafront.

1.2 Spatial Variations of Macroalgae

As discussed the shore platform of Dwarka was divided into three sections for the convenience of field sampling; the results are reported here section wise.

1.2.1 Northern Section

Transect and quadrate data sampled during three months of field survey are represented in Table 1 and Figure 3A. During April profile Cystoseira indica (Thivy & Doshi) Maırh and Centroceras clavulatum (C. Agardh) Montagne were recorded with maximum frequency at 0 m and 18 m respectively. Ulva fasciata Delile, Cystoseira indica (Thivy & Doshi) Maırh, Sargassum sp. and Hypnea pannosa J. Agardh were reported only at 0 m. Caulerpa recemosa (Forsskål) J. Agardh, Iyengaria stellata (Børgesen) Børgesen, Padina boryana Thivy and Gelidiella acerosa (Forsskål) J. Feldmann were reported only at 18 m. In June profile, Ahnfeltia plicata (Hudson) Fries dominated with high frequency. Halimeda sp. was found only in subtidal zone at 60.60 m and 71.27 m distance with low frequency. Udotea indica A. & E. Gepp. was observed only at 4 m distance. In October profile, Ulva lactuca Linnaeus was reported in both intertidal and subtidal zone with high frequencies (Table 1). Centroceras clavulatum (C. Agardh) Montagne was observed at 0 m and 53.8 m with increased frequencies of 26% and 55% respectively.

1.2.2 Central Section

Transect and quadrate data sampled during three months of field survey are represented in Table 1 and Figure 3B. In April profile, Centroceras clavulatum (C. Agardh) Montagne was reported at 6 m (14%) and 12 m (87%) with increased frequency. Cystoseira indica (Thivy & Doshi) Maırh was reported in three quadrates, with high frequency (Table 1). Udotea indica A. & E. Gepp., Ulva fasciata Delile and Padina tetrasstromatica Hauck were reported only at 6 m, 12 m and 27 m respectively. In June profile, Valoniopsis pachynema (Martens) Børgesen was observed with low frequency (22%, 15% and 2%) in all quadrates but it increased to 29% at 70.6 m. Ahnfeltia plicata (Hudson) Fries was reported at 14.6 m (10%), and thereafter at 55.6 m (10%) with same frequency. Valonia aegagropila C. Agardh was observed at 33.6 m (76%) and 40.6 m (28%) with decreased frequency. Caulerpa racemosa (Forsskål) J. Agardh was observed at 70.6 m and 85.6 m. In October profile, Ulva lactuca Linnaeus was found at 0 m (32%) and 67.8 m (50%) with high frequencies. Boodlea composita (Harvey) Brand was high at 67.8 m (10%), Gelidiella acerosa (Forsskål) J. Feldmann was observed at 0 m (10%) and 30 m (38%) with high frequencies. Rosenvingea orientalis J. Agardh was observed only at 0 m with 38% frequency. Caulerpa racemosa (Forsskål) J. Agardh var. turbinata (J. Agardh) Eubank and Valonia aegagropila C. Agardh were observed only at 67.8 m. In this section Rhodophyta dominated the subtidal zone.

1.2.3 Southern Section

Transect and quadrate data sampled during three months of field survey are represented in Table 1 and Figure 3C. In case of April profile, highest number of quadrates were demarcated on 105.5 m transect line. Centroceras clavulatum (C. Agardh) was observed at 12.5 m (14%) and 33.5 m (28%) with high frequency. Ahnfeltia plicata (Hudson) Fries was observed in all quadrates with low as well as high frequency (Table 1). Sargassum cinctum J. Agardh was found with high frequencies at 12.5 m (20%), 33.5 m (31%) and 87.5 m (41%) and low frequencies at 69.5 m (29%), 93.5 m (37%) and 99.5 m (30%). Cladophora javanica (Kützing) P. Silva was observed at 12.5 m (1%) and at 87.5 m (5%) with higher frequency. Halimeda sp. was observed in subtidal zone with high frequency. Iyengaria stellata (Børgesen) Børgesen was seen only at 33.5 m. Chlorophyta and Rhodophyta dominated the subtidal and intertidal zones respectively. In June profile, Boodlea composita (Harvey) Brand was observed with high frequencies in all quadrates but was
absent only at 16.8 m quadrat (Table 1). *Gelidiella acerosa* (Forsskål) J. Feldmann was found with high and low trend. *Sargassum cinctum* J. Agardh was observed with increasing frequencies at 16.8 m (13%), 31.8 m (16%) and 59.8 m (21%). In October profile, *Ulva lactuca* Linnaeus was found with decreasing frequency from 0 m to 20.4 m (Table 1 and Figure 3C). *Valoniopsis pachynema* (Martens) Børgesen was found with varying frequencies. *Padina boergesenii* Allender & Kraft was found at 57.4 m (2%) and 95.6 m (4%) with increasing frequency. *Lobophora varigata* (Linnaux) Womersley ex Oliveria, *Amphiroa anceps* (Lamark) Decaisne and *Corallina berteroii* Montagne ex Kützing were observed only at 38.2 m.

1.3 Temporal Variation

Temporal variations in these taxa, in the three sections of the shore platform, Dwarka are presented in Table 2. In northern section, total eleven quadrates were studied in the three sampling months, while in central section thirteen quadrates were studied and for southern section, sixteen. Total thirty six macroalgae taxa were recorded. Table-2 shows the temporal occurrence of macroalgae on the shore platform. Maximum number of taxa (26 taxa) were reported during October and minimum (14 taxa) during June. Frequency data of taxa are represented section and quadrates wise in Table 1.

1.4 Stages of Growth of Different Macroalgae Taxa

On the shore platform of Dwarka, occurrence of total 36 taxa of macroalgae were noted during the three sampling months (April, June and October; Figure 2). Total 16 taxa of Chlorophyta were identified: *Caulerpa perturarioides* (S. Gmelin) F. brevipes (J. Agardh) Svedelius, *Halimeda macroloba* Decaisne, *Halimeda tuna* (Ellis & Solander) Lamouroux and *Udotea indica* A. & E. Gepp. were found in April, June and October indicative of growing season is pre-monsoon. *Valonia aegagropila* C. Agardh and *Valoniopsis pachynema* (Martens) Bøegesen were found in June (juvenile) and October (dying) so, their growing season is in monsoon. *Caulerpa taxifolia* (Vahl) C. Agardh and *Ulva lactuca* Linnaeus were seen during April and October (juvenile condition) so, their growing seasons are in winter. *Caulepa racemosa* (Forsskål) J. Agardh occurred in April and June (in dying condition) so, its growing season is summer. Rest of the 7 taxa were identified but cannot be commented with respect to their growth stages as their occurrence was noted for once in one month only.

Total 11 taxa of Ochrophyta were identified: *Stoechospermum marginatum* (C. Agardh) Kützing was found in mature condition in October so, its growing season is in monsoon. *Lobophora variegata* (Lamouroux) Womersley ex Oliveria was seen in juvenile condition in October indicating a growing season in winter. *Padina boergesenii* Allender & Kraft was found in April and October months which implies a winter growing season. *Padina boryana* Thivy was found during April and June so its growing season is in summer. *Sargassum cinctum* J. Agardh, *Iyengaria stellata* (Børgesen) Børgesen and *Padina tetrastromatica* Hauck were found during April, June and October in similar condition so, in this case it is difficult to comment on their growing stages and season. Rest of the 4 taxa were identified but cannot be commented with respect to their growth stages because their occurrence was noted for once in one month only.

Total 9 taxa of Rhodophyta were identified: *Gelidiella acerosa* (Forsskål) J. Feldmann was found during June and October indicating a growing season in monsoon. *Corallina berteroii* Montagne ex Kützing was found during April, June and October (juvenile condition) so, its growing season is in winter. *Hypnea spinella* (C. Agardh) Kützing was seen during April and October months implying a growing period in winter. *Ahnfeltia plicata* (Hudson) Fries and *Centroceras clavatum* (C. Agardh) Montagne were found during April and June indicating growing season in summer. Rest of the 4 taxa were identified but cannot be commented with respect to their growth stages because their occurrence was noted for once in one month only.

2 Discussion

The present study shows presence of three groups of macroalgae on the shore platform found during three months’ field sampling. Taxa of Rhodophyta and Chlorophyta were found in both intertidal and subtidal zones. Ochrophyta were found in the cliffbase zone. Rhodophyta dominated the northern section during October while Chlorophyta dominated the subtidal zone of central section in all the three months and in all the three sections. *Halimeda* sp.is found only in the subtidal zone.
| Sr. No. | Name of Species | Northern Section | Central Section | Southern Section |
|---------|-----------------|-----------------|-----------------|-----------------|
|         |                 | April | June | October | April | June | October | April | June | October |
| 1       | Boodlea composita (Harvey) Brand | A     | A    | A       | A     | A    | P      | A     | P    | P      |
| 2       | Bryopsis plumosa (Hudson) C. Agardh | A     | A    | A       | A     | A    | A      | A     | A    | P      |
| 3       | Caulerpa racemosa (Forsskål) J. Agardh | P     | A    | A       | P      | A    | P      | A     | P    | A      |
| 4       | Caulerpa racemosa (Forsskål) J. Agardh var. turbinata (J. Agardh) Eubank | A     | A    | A       | A      | A    | A      | P     | A    | A      |
| 5       | Caulerpa scalpelliformis (Brown ex Turner) C. Agardh var. denticulata Borgesen | A     | A    | A       | A      | P    | A      | A     | A    | A      |
| 6       | Caulerpa sertularioides (S. Gmelin) Howe f. brevise (J. Agardh) Svedelius | P     | A    | A       | A      | A    | A      | P     | P    | P      |
| 7       | Caulerpa taxifolia (Vahl) C. Agardh | A     | A    | A       | A      | A    | P      | A     | A    | A      |
| 8       | Caulerpa veravalensis Thivy & Chauhan | A     | A    | A       | A      | A    | P      | A     | A    | A      |
| 9       | Cladophoropsis javanica (Kützing) P. Silva | A     | A    | A       | A      | A    | A      | P     | A    | A      |
| 10      | Halimeda tuna (Ellis & Solander) Lamouroux | A     | A    | A       | A      | P    | A      | A     | A    | A      |
| 11      | Halimeda sp. | A     | P    | A       | A      | P    | A      | A     | A    | A      |
| 12      | Udotea indica A. & E. Gepp. | P     | P    | A       | P      | A    | A      | P     | A    | A      |
| 13      | Ulva fasciata Delile | P     | A    | A       | P      | A    | A      | A     | A    | A      |
| 14      | Ulva lactuca Linnaeus (Juvenile) | A     | A    | P       | A      | A    | P      | A     | A    | A      |
| 15      | Valonia aegagropila C. Agardh | A     | A    | A       | P      | A    | A      | P     | A    | A      |
| 16      | Valoniopsis pachynema (Martens) | A     | A    | A       | A      | P    | A      | A     | A    | A      |
| 17      | Cystoseira indica (Thivy & Doshi) Mairh | A     | A    | A       | P      | A    | A      | A     | A    | A      |
| 18      | Iyengaria stellata (Børgesen) Børgesen | P     | A    | A       | A      | A    | A      | A     | A    | A      |
| 19      | Lobophora variegata (Lamouroux) Womersley ex Oliveria | A     | A    | A       | A      | A    | A      | A     | A    | A      |
| 20      | Padina boergeseni Allender & Kraft | A     | A    | A       | A      | A    | A      | A     | A    | P      |
| 21      | Padina boryana Thivy | P     | A    | A       | A      | A    | A      | A     | A    | A      |
| 22      | Padina tetrastromatica Hauck | A     | A    | A       | P      | A    | A      | A     | A    | A      |
| 23      | Rosenvingea orientalis J. Agardh | A     | A    | A       | A      | A    | P      | A     | A    | A      |
| 24      | Sargassum cinctum J. Agardh | A     | A    | A       | A      | A    | P      | P     | P    | P      |
| 25      | Sargassum Sp.-1 | A     | A    | A       | A      | A    | P      | A     | A    | A      |
| 26      | Sargassum Sp.-2 | A     | A    | A       | A      | P    | A      | A     | A    | A      |
| 27      | Stoechospernum marginatum (C. Agardh) Kützing | A     | A    | A       | A      | A    | A      | A     | A    | P      |
| 28      | Ahnfeltia plicata (Hudson) Fries | A     | P    | A       | A      | P    | A      | P     | A    | A      |
| 29      | Amphipora anceps (Lamarck) Decaisne | A     | A    | A       | A      | A    | A      | A     | A    | A      |
| 30      | Centroceras clavulatum (C. Agardh) Montagne | P     | A    | P       | A      | P    | P      | P     | P    | P      |
| 31      | Corallina berteroi Montagne ex Kützing | A     | A    | A       | A      | A    | A      | A     | A    | A      |
| 32      | Gelidiella acerosa (Forsskål) J. Feldmann | P     | A    | P       | A      | P    | P      | A     | P    | P      |
| 33      | Gracilaria corticata (J. Agardh) J. Agardh | A     | A    | A       | A      | A    | A      | A     | A    | A      |
| 34      | Hypnea pannosa J. Agardh | P     | A    | A       | A      | A    | A      | A     | A    | A      |
| 35      | Hypnea spinella (C. Agardh) Kützing | A     | A    | A       | A      | A    | A      | A     | A    | P      |
| 36      | Laurencia papillosa (C. Agardh) Greville | A     | A    | P       | A      | A    | A      | A     | A    | A      |
Taxa of Rhodophyta were found in highest number (6 species) in October and less (3 species) in June. Members of Chlorophyta were found in highest number (9 species) in June. Members of Ochrophyta (5 species) were found in highest number in April. During June, only one species of Ochrophyta (Sargassum cinctum J. Agardh) was found. *Iyengaria stellata* was found throughout the three sampling months. *Caulerpa* species dominated during April as compared to June and October during the sampling months.

*Caulerpa* sp. (*C. racemosa* (Forsskål) J. Agardh, *C. sertularioides* (S. Gmelin) F. brevipes (J. Agardh) Svedelius, *C. veravalensis* Thivy & Chauhan, *C. taxifoila* (Vahl) C. Agardh) were found in mature condition in April which indicated summer growth stage. *Hypnea spinella* (C. Agardh) Kützing and *Stoechospermum marginatum* (C. Agardh) Kützing was in mature condition only during October which showed monsoon growth stage. *Ulva* species (*U. lactuca* Linnaeus and *U. fasciata* Delile) were found in Juvenile condition in October.

Various researchers have studied seasonal distribution of marine macroalgae in Indian waters. They have studied the seasonal variability of macroalgae in the east and west coast but did not comment on the dynamics of the macroalgae. Thakur et al., (2008) have worked on the seasonal variation in biomass and species composition of seaweeds in port Okha during May 2004 to April 2005 and reported 62 species during the entire study period. Studies conducted for quantifying the standard seaweeds from May 2004 to April 2005 showed an average biomass value of 3.10 kg fresh wt/m²/month with maximum being 6.60 kg fresh wt/m² in April. Dhargalkar and Desmukhe (1996) have worked on the subtidal marine algae of Dwarka coast and reported 35 marine algal species. They encountered maximum numbers of species at 5-8m depth and found red algae species dominating this depth. Other authors have studied seasonal variability in the species of macroalgae. Ramamooorthy et al., (2012) have presented an assessment of reef associated biota in the Pirotan Island, Gulf of Kachchh, Gujarat and reported 89 species of fauna and 31 species of flora (seaweeds and seagrasses).

This study intends to report the macroalgae taxa on the basis of a systematic field inventory with reference to presence and absence of the taxa and its stage of growth. This kind of study when done on routine annual basis can bring out the macroalgal dynamics on spatial and temporal domain for the study area.

### 3 Material and methods

#### 3.1 Study Area

For macroalgae growth, geographical, geological, topographical and physical nature of the shore is very important. The rocky coast has vertical zonation worldwide (Woodward, 2003): it provides good platform and stable coastal environment compared to that of soft sediments coasts like beaches and spits. Shore platform represents a case environment where majority of macroalgae species grow with a firm substratum attachment.

Gujarat coast of India represents the northwestern most part of peninsular India. This coastline occurs within geographical limits of 20°00'-24°45' N and 68°00'-78°30'E. It is 1,650 km long with 164,200 km² continental shelf (Jha, et al., 2009). It extends in the form of four major coastal ecological components: i) Kori creek ii) Gulf of Kachchh iii) Saurashtra coast from Okha to Porbandar and iv) Gulf of Kambhat. The substratum is rocky in many parts, which provides suitable environment for macroalgae growth (Chakraborty and Bhattacharya, 2012). The Saurashtra coast, which runs for an approximate length of 985 km, is characterized by rocky, sandy and muddy intertidal zones, harboring rich and varied flora and fauna (Gohil and Kundu, 2012).

The present study was carried out on the shore platform at Dwarka, located on the Saurashtra coast (22°14’22”-22°14’38”N and 68°57’15”- 68°57’25” E) (Figure 1). Total length of the study area is 572.28 m, maximum width sampled is 105.5 m and covers a surface area of 60375.54 m². Previous surveys of marine algal resources along the Gujarat coast, performed at the intertidal zone, have revealed great diversity of marine algae in this region (Dhargalkar and Desmukhe, 1996).

#### 3.2 Field data collection

For the present study, the study area was divided into three sections (in North-South direction): (i) Northern, (ii) Central and (iii) Southern sections for convenience
of field sampling. Field sampling of macroalgae was planned in the months of April, June and October, 2013 considering sampling feasibility. These three months: April, June and October represent three different seasons: summer (March-May), monsoon (June-August) and post-monsoon (October-December) respectively. Field surveys/sampling were performed during the low tides. For qualitative and quantitative assessment GPS (Spheroid and Datum: WGS 84) tagged line transect method was used. Maximum transect length surveyed is 105.5 m and minimum is 24m. Length of transect lines depended on the tidal exposure of the shore platform during the field surveys. Maximum depth of the subtidal zone sampled for macroalgae is 0.5m.

For quantitative assessment of the marine algae in the given area, line transect was laid perpendicular to the coast from land to sea with the help of a long rope (50 m) (Dhargalkar and Kavlekar, 2004). A sampling point along the rope is marked depending on the gradient and exposure of intertidal and subtidal areas. In Saurashtra coast, the tidal amplitude is very high as compared to other parts of the west coast and the entire east coast of India. Growth of seaweeds in intertidal and shallow subtidal regions can be easily observed in this area as the spring tides expose the intertidal area up to a maximum length of 1 km (Jha, et al., 2009). Each of the three sections on the shore platform was represented by one transect line: thus resulting nine transect lines over three months’ sampling. Quadrates of 1 m² were positioned on the transect lines wherever the algae growth, density and diversity were high. Total thirty nine quadrates were performed on the transect lines wherever the algae growth, density and diversity were high. Total thirty nine quadrates were performed on the nine transect lines. GPS tagged photos of quadrates were taken for further analysis. Macroalgae species present within the quadrates were sampled. All specimens were identified and the specific numbers of individuals were registered for quantitative assessment of frequency.

3.3 Field data analysis
Collected macroalgae samples were taken to laboratory for preparation of herbarium sheets and specimen identification. Morphological criteria and reproductive structure were analyzed for taxa identification. Cladograms were prepared for identifying species in order to generate classification statistics (number of genera and species pertaining to different classes) (Figure 2).
For understanding their spatial variation, transect and quadrate data were analyzed and are graphically represented as cross profiles of shore platform with embedded bar charts showing frequency of different macroalgae groups (Figure 3). In the cross profile, straight line is representing the transect line scaled to ground distance. Frequency of algal species encountered at the transect intercepts are represented as bar charts. X-axis of the bar chart represents macroalgae groups present while Y-axis shows their respective frequencies (in percentage).

Authors’ contribution
As part of my doctoral research program, myself, Ms. Dimpal Sanghvi carried out this study. I performed field data collection, data analysis and have written the paper. Ms. Nandini Ray Chaudhury helped in analysis of field data and gave guidance to organize the paper. Dr. B.K. Jain, research guide, gave overall guidance and helped in editing the manuscript and submitting the same for peer-review.

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Figure 2 Cladogram of identified species of Macroalgae sampled from shore platform, Dwarka

Figure 3 Cross profile showing frequency of different macroalgae groups at transect intercepts.
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Figure 3 Transect lines and Quadrates sampled during three months on shore platform, Dwarka: A) Northern Section, B) Central Section and C) Southern Section
Table 1 Frequency of Macroalgae species based on Line Transect and Quadrate survey on the shore platform, Dwarka

| Sections    | Months   | Quadrate-1 (0m) | Quadrate-2 (18m) | Quadrate-3 (24m) | Quadrate-4 (4m) | Quadrate-5 (6m) | Quadrate-6 (38.8m) |
|-------------|----------|-----------------|-----------------|-----------------|----------------|----------------|-------------------|
| Northern    | April    | Caulerpa sertularioides (8%) | Caulerpa racemosa (8%) | Caulerpa sertularioides (2%) | Ulva fasciata (7%) | Ulva fasciata (13%) | Ulva fasciata (14%) |
|             |          | Udotea indica (6%) | Ulva fasciata (13%) | Ulva fasciata (14%) | Padina boryana (3%) | Padina boryana (3%) | Padina boryana (3%) |
|             |          | Cystoseira indica (43%) | Padina boryana (3%) | Padina boryana (3%) | Iyengaria stellata (0.25%) | Iyengaria stellata (0.25%) | Iyengaria stellata (0.25%) |
|             |          | Centroceras clavulatum (10%) | Centroceras clavulatum (22%) | Centroceras clavulatum (22%) | Gelidiella acerosa (7%) | Gelidiella acerosa (7%) | Gelidiella acerosa (7%) |
|             | June     | Ahnfeltia plicata (18%) | Ahnfeltia plicata (67%) | Ahnfeltia plicata (77%) | Halimeda sp. (29%) | Halimeda sp. (29%) | Halimeda sp. (29%) |
|             |          | Udotea indica (18%) | Ahnfeltia plicata (24%) | Ahnfeltia plicata (24%) | Padina tetrastromatica (7%) | Padina tetrastromatica (7%) | Padina tetrastromatica (7%) |
|             | October  | Ulva lactuca (7%) | Ulva lactuca (14%) | Ulva lactuca (45%) | Ulva lactuca (45%) | Ulva lactuca (45%) | Ulva lactuca (45%) |
|             |          | Gracilaria corticata (31%) | Gelidiella acerosa (58%) | Gelidiella acerosa (58%) | Ulva lactuca (45%) | Ulva lactuca (45%) | Ulva lactuca (45%) |
|             |          | Centroceras clavulatum (26%) | Centroceras clavulatum (55%) | Centroceras clavulatum (55%) | Laurencia papillosa (25%) | Laurencia papillosa (25%) | Laurencia papillosa (25%) |
| Central     | April    | Udotea indica (9%) | Ulva fasciata (13%) | Caulerpa racemosa (4%) | Caulerpa racemosa (4%) | Caulerpa racemosa (4%) | Caulerpa racemosa (4%) |
|             |          | Cystoseira indica (14%) | Centroceras clavulatum (87%) | Centroceras clavulatum (87%) | Cystoseira indica (81%) | Cystoseira indica (81%) | Cystoseira indica (81%) |
|             |          | Centroceras clavulatum (14%) | Padina tetrastromatica (7%) | Padina tetrastromatica (7%) | Padina tetrastromatica (7%) | Padina tetrastromatica (7%) | Padina tetrastromatica (7%) |
Continued Table 1

| Sections       | Month     | Quadrate-1       | Quadrate-2       | Quadrate-3       | Quadrate-4       | Quadrate-5       | Quadrate-6       |
|----------------|-----------|------------------|------------------|------------------|------------------|------------------|------------------|
| Central Section| June      | 14.6m (Q-1)      | 33.6m (Q-2)      | 40.6m (Q-3)      | 55.6m (Q-4)      | 70.6m (Q-5)      | 85.6m (Q-6)      |
|                |           | Name of Sp. (Frequency) | Name of Sp. (Frequency) | Name of Sp. (Frequency) | Name of Sp. (Frequency) | Name of Sp. (Frequency) | Name of Sp. (Frequency) |
|                |           | Valoniopsis pachynema (22%) | Valonia aegagropila (76%) | Valonia aegagropila (28%) | Valoniopsis pachynema (2%) | Halimeda sp. (1%) | Caulerpa scalpelliformis (18%) |
|                |           | Gelidiella acerosa (17%) | Valoniopsis pachynema (15%) | Ahnfeltia plicata (10%) | G. acerosa (60%) | Ahnfeltia plicata (10%) | Caulerpa racemosa (16%) |
|                |           |                   |                  |                  |                  |                  |                  |
| Southern Section| October   | 0m (Q-1)         | 30.0m (Q-2)      | 67.8m (Q-3)      |                  |                  |                  |
|                |           | Ulva lactuca (32%) | Boodlea composita (4%) | Ulva lactuca (50%) |                  |                  |                  |
|                |           | Boodlea composita (4%) | Sargassum sp. -1 (18%) |                  | Caulerpa racemosa (19%) |                  |                  |
|                |           | Rosenvingea orientalis (38%) | Padina sp.(4%) |                  | Valonia aegagropila (16%) |                  |                  |
|                |           | Sargassum sp.-2 (7%) | Gelidiella acerosa (38%) |                  |                  |                  |                  |
|                |           | Gelidiella acerosa (10%) |                  |                  |                  |                  |                  |
|                |           |                   |                  |                  |                  |                  |                  |
|                |           | 12.5m (Q-1)      | 33.5m (Q-2)      | 69.5m (Q-3)      | 87.5m (Q-4)      | 93.5m (Q-5)      | 99.5m (Q-6)      |
|                |           | Cladophoropsis javanica (1%) | Caulerpa racemosa (5%) | Caulerpa racemosa (23%) | Caulerpa veravalensis (31%) | Halimeda sp. (20%) | Caulerpa sertularioides (50%) |
|                |           | Sargassum cinctum (20%) | Sargassum cinctum (31%) | Caulerpa sertularioides (4%) | Caulerpa veravalensis (17%) |                  | Caulerpa veravalensis (4%) |
|                |           | Ahnfeltia plicata (18%) | Iyengaria stellata (1%) | Udotea indica (1%) | Halimeda sp. (17%) | Caulerpa sertularioides (8%) | Sargassum cinctum (30%) |
|                |           | Centroceras clavulatum (14%) | Centroceras clavulatum (28%) | Sargassum cinctum (29%) | U. indica (6%) | Caulerpa taxifolia (3%) | Ahnfeltia plicata (29%) |
|                |           | Ahnfeltia plicata (17%) | Padina sp.(3%) | Cladophoropsis javanica (5%) |                  | Caulerpa racemosa (1%) |                  |
|                |           |                   |                  | Ahnfeltia plicata (6%) |                  |                  |                  |
|                |           |                   |                  |                  |                  |                  |                  |

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| Sections | Month | Quadrade-1 | Quadrade-2 | Quadrade-3 | Quadrade-4 | Quadrade-5 | Quadrade-6 |
|----------|-------|------------|------------|------------|------------|------------|------------|
| **Quadrate distance** | **June** | Name of Sp. (Frequency) | Name of Sp. (Frequency) | Name of Sp. (Frequency) | Name of Sp. (Frequency) | Name of Sp. (Frequency) | Name of Sp. (Frequency) |
| 0m (Q-1) | Boodlea composita | Boodlea composita | 16.8m (Q-3) | Caulerpa racemosa | Caulerpa racemosa | Boodlea composita |
| 8m (Q-2) | (27%) | (55%) | 31.8m (Q-4) | (78%) | (22%) | (19%) |
| **Quadrate distance** | **October** | Name of Sp. (Frequency) | Name of Sp. (Frequency) | Name of Sp. (Frequency) | Name of Sp. (Frequency) | Name of Sp. (Frequency) | Name of Sp. (Frequency) |
| 0m (Q-1) | Ulva lactuca | Ulva lactuca | 20.4m (Q-3) | Caulerpa sertularioides | Valoniopsis pachynema | 95.6m (Q-5) |
| 7m (Q-2) | (32%) | (30%) | 57.4m (Q-4) | (12%) | (20%) | Valoniopsis pachynema |
| **Note:** Colour used in this table indicate different phyla of macroalgae: **Green colour=Chlorophyta,** **Brown colour=Ochrophyta** and **Red Colour=Rhodophyta** | Ulva lactuca | (8%) | Halimeda sp. (10%) | | (50%) | Halimeda tune (4%) |