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Original Article

Habitat preference of seaweeds at a tropical island of southern Malaysia

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Abstract

Merambong Island has a diverse assemblage of marine organisms; however, reclamation activity has changed the nature of the island. Hence, this research was conducted to provide the latest inventory of algae throughout a 12-month assessment with correlations to their specific habitats namely sandy, rocky, muddy, and mangrove. The single line transect-quadrat method was used to collect samples along temporary 25-meter transects with 5 replications at each site. The specimens were processed in the laboratory and deposited in the herbarium at Algae Herbarium, National University of Malaysia. A total of 46 species were identified including 22 species of Chlorophyceae, six species of Phaeophyceae, and 17 species of Rhodophyceae. The principal component analysis plot shows the species forming groups according to specific habitat. The cosmopolitan species were *Chaetomorpha* spp. that are able to adapt in various types of habitats. Thus, Merambong Island has great seaweed diversity with specific habitat preference.

Keywords: seaweeds, diversity, habitat preference, tropical island

1. Introduction

Seaweeds, known as marine benthic algae, have three main classes including Chlorophyceae, Phaeophyceae, and Rhodophyceae (Ahmad, 1995; Bilgrami & Saha, 1992; Chapman, 1970; Lee, 1999). Seaweeds are marine organisms that are ecologically (Asmida, Noor Akmal, Ahmad, & Sarah Diyana, 2017; Mijan Uddin, Ahmad, & Asmida, 2007), economically (Ab Kadir *et al.*, 2014; Chan, Mirhosseini, Taip, Ling, & Tan, 2013), and pharmacologically (Ab Kadir, Ahmad, Ismail, & Abdul Jabbar, 2016; Daud, Nawi, Ismail, & Tawang, 2015) crucial to the marine ecosystem. They form an underwater forest as the primary producer of sources of food for marine herbivores, provide shelter for fish, and give protection to marine endophytes (Gan, Siti Aisyah, & Maya Sofia, 2011; Prathep, Pongparadon, Darakrai, Wichachucherd, & Sinutok, 2011; Wong, Muta Harah, Japar Sidik, & Arshad, 2012).

Vertical distributions of algae are determined according to the coastal zones: supralittoral zone, littoral zone, and sublittoral zone (Pedersen, Kraemer, & Yarish, 2008; Surey-Gent & Morris, 1987). Horizontal distribution of seaweed depends on the presence of substratum, tide action, and wave amplitude (Ahmad & Rusea, 1994; Trono & Ganzon-Fortes, 2004). The most common habitats for seaweed communities are sandy and rocky. However, two habitats, namely muddy and mangrove which provide less

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substrate for the attachment of the holdfast, contribute to a fewer number of seaweed species (Joanna & Trevor, 1990).

Merambong Island is a small isolated island located at the western end of Johor Straits, near the international water border of Malaysia and Singapore. The island is characterized by a warm tropical climate with an average sea temperature of 28.9 °C. It has a stable environment and provides niches for seaweed communities. Historically, the island was pristine, yet the purity of the island has been disturbed by land reclamation activity adjacent to the island. This problem might cause massive environmental changes that result in negative impacts on the seaweed communities of the island such as extinction of the organisms. It was observed that the muddy shore at the southern part of the island increased in area compared to a field survey in 2011. Likewise, the number of species has declined and the environmentally sensitive species, such as *Halymenia maculata*, have become extinct (Jasni, unpublished).

Thus, this study was conducted to record and describe the extensively diverse marine algae and to examine the presence of species according to their habitat preferences. This study provides recent information with specific habitat preferences of the seaweeds at this island and supports further research on marine algae, especially the species which are sensitive to environmental change. In addition, seaweeds can be excellent sources of anticancer, antimicrobial, antioxidant, and antiplasmodial agents (Ana Ligia, Rafael, & Hosana, 2012; Babu, Varadharajan, Soundarapandian, & Balasubramaniam, 2010; Flewelling, Johnson, & Gray, 2015; Hazalin *et al.,* 2009).

2. Materials and Methods

2.1 Study area

The sampling sites are featured by sandy, rocky, muddy, and mangrove shores (Figure 1). In particular, rocky and muddy shores were the most exposed study sites, followed by mangrove shore (Figure 1). However the presence of mangrove trees such as *Rhizophora* sp., *Bruguiera* sp., and *Sonneratia* sp. reduced the impact of water currents and waves. However, the sandy shore had moderate impact of wave exposure. Overall, the island faced moderate impact of sedimentation triggered from the land reclamation activity of the Forest City project located at the northern part of the island. The GPS locations of each sampling site were recorded using Garmin Rino 130 as tabulated in Table 1.

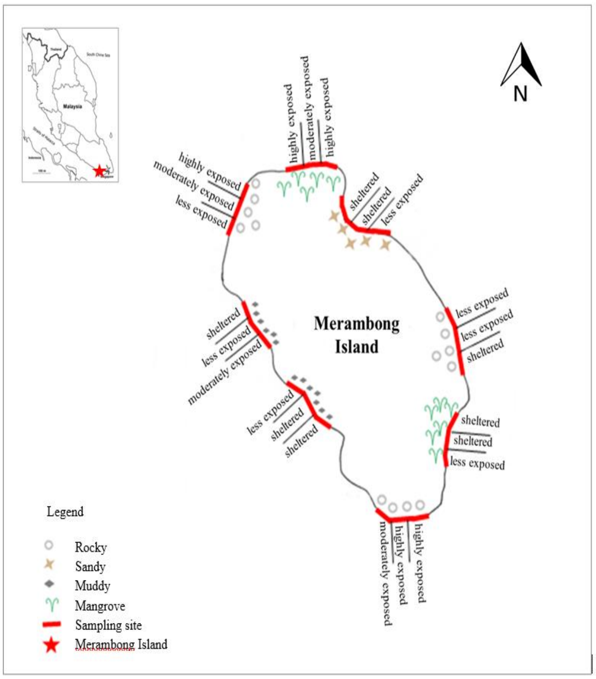

Figure 1. Location of the sampling sites at the southern region of Peninsular Malaysia. Merambong Island is located in the Straits of Johor and consists of sandy shore, rocky shore, muddy shore, and mangrove habitat.

Table 1. Global Positioning System (GPS) data recorded during the fieldwork.

Types of shore	GPS location
Sandy	N 01º 18.977’ E 103º 36.599’
Rocky	N 01º 18.958’ E 103º 36.519’
Muddy	N 01º 18.923’ E 103º 36.531’
Mangrove	N 01º 18.966’ E 103º 36.548’

2.2 Specimen collection

The samples were collected between February 2015 and January 2016 using the non-destructive line transect-quadrat method. In total, 6240 quadrats were analyzed during the 12-month observation period. The species that occurred within each coastal zone were collected and recorded by placing a temporary quadrat (50×50 cm) subdivided into smaller (10×10 cm) squares with 5 replications for each site. The collected samples were kept in plastic bags and then processed in the laboratory for identification purposes. The environmental data such as temperature, pH, salinity, dissolved oxygen, nitrate, and orthophosphate were recorded using a Hanna Instruments Model HI98194 and HachKit Model DR/2000.

2.3 Specimen storage

The specimens were cleaned from the clasping substrate and sorted according to their genus or species. Mixtures of formalin solution and seawater were prepared for preservation of the samples. The specimens with complete thallus were chosen for dry storage at the herbarium in the Algae Herbarium of National University of Malaysia.

2.4 Specimen identification

Identification keys and books were used as references to identify the seaweeds (Ahmad, 1995; Phang, 2007; Prathep *et al.*, 2001; Trono & Ganzon-Fortes, 2004). Small and delicate samples such as *Chaetomorpha* spp. and *Polysiphonia* sp. were observed under a compound light microscope. The genera such as *Padina* and *Gracilaria* were cross-sectioned using surgical blades to observe the sizes and shapes of the cells.

2.5 Data analysis

The quadrats and subquadrats were analyzed in terms of the coverage, density, and frequency of every individual of each seaweed species. PAST Software version 2.17c was used to analyze the value of species richness, species evenness, and dominance of the species using the diversity indices such as Shannon Wiener Index, Shannon Evenness Index, and Simpson's Index. Moreover, the correlation between the species and the habitat were evaluated using principal component analysis (PCA).

3. Results and Discussion

Physicochemical data were recorded for each month of the time period (Table 2). Physicochemical data were significantly different among the sampling sites. Sandy and rocky shores showed fewer changes in value of the environmental data throughout the 12-month data collection period (Table 2). In contrast, the muddy shore had slightly lower dissolved oxygen (3.23 mg/L) and higher content of nitrate (0.09 mg/L NO_3^-), phosphate (0.15 mg/L PO_4^{3-}), pH (7.95), and temperature (27.98 °C). During the decomposition process the nitrate and phosphate ions are released to the muddy environment which subsequently increases the pH and temperature. The mangrove, on the other hand retained a lower temperature (26.9 °C), dissolved oxygen (3.27 mg/L), and pH (7.83). The leaves of the mangrove provide shelter and reduce the light intensity which contributed to the lower temperature in the mangrove environment (Petsut, Chirapart, & Keawnern, 2012). In addition to the variation in the physicochemical data among sampling sites, a diversity of seaweeds was also observed.

A total of 25 genera, including 46 species of seaweeds, were identified from Merambong Island. The most diversified class was represented by Chlorophyceae (11 genera) followed by Rhodophyceae (10 genera) and Phaeophyceae (4 genera). The collected green algae included *Anadyomene plicata, Avrainvillea erecta, A. obscura, Boodlea composita, Bryopsis pennata, B. plumosa, Caulerpa racemesa, C. sertularioides, Chaetomorpha aerea, C. crassa, C. ligustica, C. linum, C. minima, Chlorodesmis fastigiata, Cladophora sericea, Cladophoropsis membranacea, Halimeda discoidea, Ulva clathrata, U. compressa, U. intestinalis, U. lactuca,* and *U. reticulata.*

The brown algae found in this study were *Canistro-carpus cervicornis, D. dichotoma, Ectocarpus siliculosus, Padina australis, P. minor*, and *Sargassum polycystum*. Moreover, the red algae found were *Acanthophora spicifera, Centroceras* sp., *Ceramium flaccidum, Gelidiella acerosa, Ceratodictyon intricatum, Gracilaria arcuata, G. blodgetti, G. changii, G. coronopifolia, G. salicornia, G. verrucosa, Hypnea cervicornis, H. spinella, Jania adhaerens, Laurencia flexilis, L. intricata, Polysiphonia coacta*, and *Solieria robusta.*

Chlorophyceae had wide distribution and the highest number of species (22 species) recorded in every type of habitat which indicated that Chlorophycean members had fewer habitat preferences compared to others. The Rhodophycean species were obtained in all types of habitat except at the muddy shore (Figure 2). Phaeophyceae species, on the other hand, were found predominantly in the rocky habitat (Figure 2). They demonstrated that brown algae had a high habitat preference for the rocky habitat for survival (Wong *et al.*, 2012).

A principle component analysis (PCA) was also performed using percent coverage of all algae species found along the line transect in each type of habitat. Figure 3 shows the correlation of the species and habitats by grouping the algae species according to their specific habitats. The biggest circle belongs to the sandy and rocky habitats. Meanwhile, the muddy and mangrove habitats with a small number of species are illustrated by the smaller circles. Some of the species existed in multiple habitats as shown by the overlapping circles in the diagram. Seaweed communities showed positive results on habitat preference where some of the species tended to grow in a specific habitat to survive according to their ecological and environmental needs (Chaverri & Samuels, 2013).

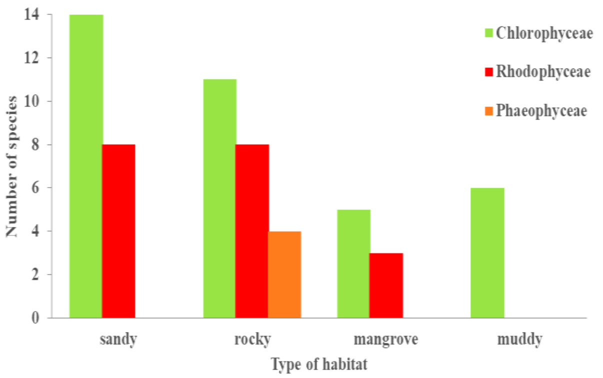

Figure 2. Bar graph shows the number of species according to their habitat. Chlorophyceae occurs in all types of habitats and is similar to Rhodophyceae which occurs in all types of habitats except muddy areas. However, Phaeophyceae occurred specifically in the rocky habitat.

Table 2. Summary of *in-situ* environmental parameter data collected during the 12-month observation period.

In-situ data	Sandy		Rocky		Muddy		Mangrove	
	Value	± SEM	Value	± SEM	Value	± SEM	Value	± SEM
Nitrate (mg/L NO_3^-)	0.01	±0.003	0.03	±0.003	0.09	±0.012	0.04	±0.009
Orthophosphate (mg/L PO_4^{3-})	0.01	±0.001	0.09	± 0.000	0.15	±0.000	0.13	±0.001
Temperature (°C)	27.38	±0.074	27.85	±0.078	27.98	±0.064	26.9	±0.083
Salinity (PSU)	27.78	±1.015	25.17	±1.683	29.09	±0.390	25.68	±1.380
pH	8.09	±0.012	8.46	±0.009	7.95	±0.110	7.83	±0.127
Dissolved oxygen (mg/L)	6.75	±0.171	6.41	±0.269	3.23	±0.151	3.27	±0.400

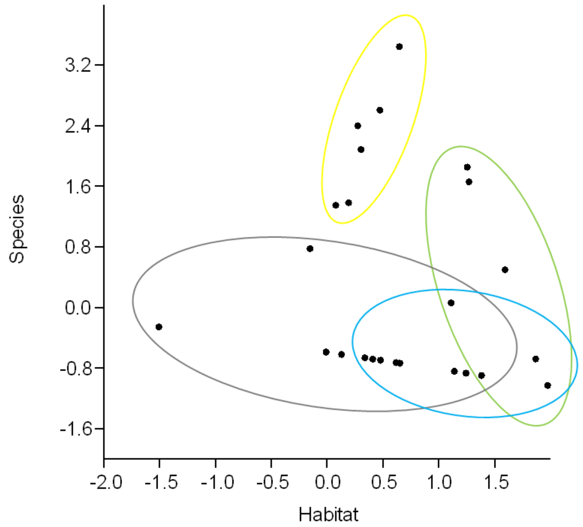

Figure 3. The principal component analysis diagram shows the grouping of the seaweeds species in correlation to their specific habitat (grey=sandy; blue=rocky; green= mangrove; yellow=muddy).

Species richness was constantly high in sandy (1.964±0.149) and rocky (1.797±0.091) habitats since the values were in the range of 1.5-3.0 (Figure 4a). Both habitats had stable environments with abundant amounts of substrate for the holdfast. The number of species for each site showed greater quantities towards the end of the collection period. In the sandy habitat, two months showed a slightly lower diversity in April 2015 (1.542) and May 2015 (1.158) which was possibly due to the equinox extremely dry and hot weather which resulted in a decrease in the number of sensitive species (Crane, 1981).

The most common species found in the sandy habitat were *Chaetomorpha* spp., *Ulva compressa,* and *U. intestinalis* followed by *Gracilaria salicornia* (Table 3). Rare species were recorded during the end of collection period, namely *Anadyomene plicata*, *Chaetomorpha crassa,* and *Solieria robusta*. The presence of fine and coarse sand particles in the habitat contributed good penetration for the holdfast of *Chlorodesmis fastigiata* and *Halimeda macroloba* which were characterized by the bulbous-type holdfast. The holdfast consisted of a complex ramified rhizoid which penetrates into the sand and holds the sand particles and pebbles to gain stability during high water current and wave impact (Blaxter, Russell, & Yonge, 1980; James & John, 2004).

The rocky shore was the site with the second highest diversity (Figure 4a). The common species for this habitat were *Ulva lactuca* and the *Chaetomorpha* spp. while *Centroceras* sp. was recorded as a rare species (Table 3). The rocky shore provided protection from the impact of waves and it was a great spot with various sizes of substrate for attachment. The Phaeophytes such as *Padina* spp. and *Sargassum polycystum* had high preference for growth in the rocky environment because of the unique matted-type holdfast. The holdfast needed to attach laterally to a stable and strong substrate for growth. In addition, the rocky habitat also provided for attachment of delicate specimens, such as *Chaetomorpha* spp., for the formation of a green 'mat' on the rocks.

The pattern for species richness of the mangrove habitat demonstrated only small changes (Figure 4a) from month to month since the seaweeds were fully protected from the impact of waves and water current. Mangrove trees have unique roots which provide protection and attachment for seaweeds (Gan *et al.*, 2011). The habitat exhibited a low diversity (0.733±0.073) and stable environment for *Cladophoropsis membranacea* which was the dominant species (Table 3). The species were found to be unique to the mangrove habitat which formed a wide and large 'mat' in the shady areas of the supralittoral and littoral zones of the island. These observations suggested that the species could tolerate the extreme environmental conditions in the spray zone such as the impact of the wind, air, and low tide (Titley, Neto, & Farnham, 1998). The branching system of the thallus was observed to grow laterally on the substrate surface which was a unique feature of capturing and preserving water (Wiebe Hendrik, Wytze, Jeanine, & Chris, 1992).

On the other hand, the muddy habitat had the lowest diversity throughout the collection period (0.969±0.061). The environment was unstable with relatively moderate to high tidal amplitude which were the main factors contributing to the low algal diversity (Crane, 1981; Wong *et al.,* 2012). Furthermore, the pattern of species richness fluctuated throughout the assessment period (Figure 4a) which suggested only a small number of changes each month. The dominant species in the area were *Avrainvillea erecta* and *Chlorodesmis fastigiata* (Table 3). The muddy habitat was also very unstable for the growth of other seaweeds and the plants detached easily from the muddy surface due to the very fine size of the substrates and high sedimentation during high tide and wave impact (Paul-Chavez & Riosmena-Rodrigues, 2000; Sheremet & Stone, 2003). The green algae *Avrainvillea erecta* and *Chlorodesmis fastigiata* could survive in this habitat since their holdfast could penetrate deeply into the muddy sediment.

Species evenness for each habitat was consistently high throughout the 12-month observation period (Figure 4b) and the number of individuals was distributed equally among the species. The values are expected to decline if there is an increase in the number of species. For example, in the sandy and rocky habitats, the number of individuals collected was unevenly distributed with small changes because the sites had a greater number of species. The species evenness in the mangrove area had the lowest value (0.808±0.018) because only *Cladophoropsis membranacea* was dominant in each month.

Highest dominance was observed in the sandy (0.811±0.025) and rocky (0.795±0.017) environments (Figure 4c) because both habitats had high species diversities. Several numbers of species were dominant in the habitat as mentioned earlier. The mangrove area had low dominance (0.449±0.029) because of the low number of species (6 species) and only one species was consistently observed as the dominant species. In the muddy area, the species dominance value (0.591±0.019) was unstable and resulted in a fluctuating bar graph across the observation period because the habitat was unfavorable for most of the seaweed species.

Thus, Merambong Island attained high species richness and had great potential to support seaweed communities by providing various types of habitats. Furthermore, the stable environmental conditions led to suitability of the habitats for seaweeds to live at the island.

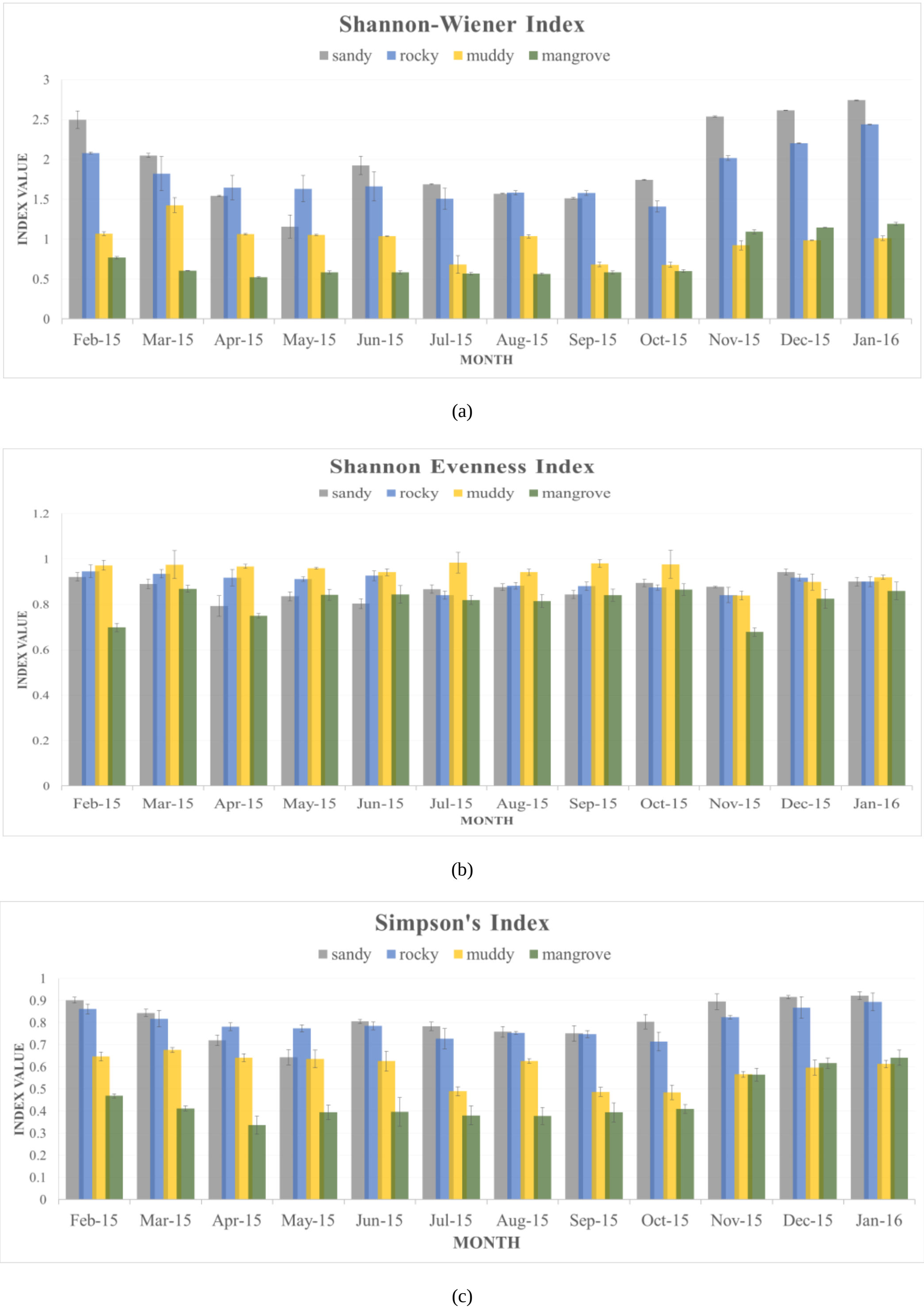

Figure 4. Bar graph shows the changes in the index values over the 12-month observation period: (a) Shannon-Wiener Diversity Index; (b) Shannon Evenness Index (c); and Simpson's Richness Index.

The land reclamation activity adjacent to the island was a problematic issue causing high sedimentation and increased water turbidity. The consequences from the activity might result in a decline of seaweed diversity. Therefore, preservation and conservation of the communities are important issues due to the large number of rare species that live at the island. Awareness should be raised in order to preserve and conserve the seaweed communities.

Table 3. Presence of seaweeds according to their specific types of habitat.

List of seaweeds	Types of habitat			
	Sandy	Rocky	Muddy	Mangrove
CHLOROPHYCEAE				
Anadyomene plicata	+ *r*	-	-	-
Avrainvillea erecta	+	+	+ *c*	-
Avrainvillea obscura	+	-	+ *r*	-
Boodlea composita	+	-	-	-
Bryopsis pennata	+	+	-	-
Bryopsis plumosa	+	-	-	-
Caulerpa racemosa	+	-	-	-
Caulerpa sertularioides	+	-	-	-
Chaetomorpha aerea	-	+ *c*	+	+
Chaetomorpha crassa	+ *r*	-	-	-
Chaetomorpha ligustica	+ *c*	+ *c*	+	+
Chaetomorpha linum	+ *c*	+ *c*	+	+
Chaetomorpha minima	+ *c*	+ *c*	+	+
Chlorodesmis fastigiata	+	+	+ *c*	-
Cladophora sericea	-	+	-	-
Cladophoropsis membranacea	+	+	-	+ *c*
Halimeda discoidea	-	+	-	-
Ulva clathrata	+	+ *c*	-	-
Ulva compressa	+ *c*	+ *c*	-	-
Ulva intestinalis	+ *c*	- *c*	-	-
Ulva lactuca	+	+ *c*	-	-
Ulva reticulata	+	+	-	-
RHODOPHYCEAE				
Acanthophora spicifera	+	+	-	-
Centroceras sp.	-	+ *r*	-	-
Ceramium flaccidum	+	-	-	-
Gelidiella acerosa	+	+	-	-
Ceratodictyon intricatum	+	+	-	+
Gracilaria arcuata	+	-	-	-
Gracilaria blodgetti	+	-	-	-
Gracilaria changii	+	-	-	-
Gracilaria coronopifolia	+	-	-	-
Gracilaria salicornia	+ *c*	+	-	-
Gracilaria verrucosa	-	+	-	-
Hypnea cervicornis	+	+	-	-
Hypnea spinella	+	-	-	-
Jania adhaerens	+	+	-	-
Laurencia flexilis	+	-	-	-
Laurencia intricata	-	+	-	+
Polysiphonia coacta	+	-	-	+
Solieria robusta	+ *r*	-	-	-
PHAEOPHYCEAE				
Canistrocarpus cervicornis	-	-	-	+
Dictyota dichotoma	+	-	-	-
Ectocarpus siliculosus	-	+	-	-
Padina australis	+	+	-	-
Padina minor	-	+	-	-
Sargassum polycystum	+	-	-	-
TOTAL	37	26	7	9
GRAND TOTAL	46			

+ present; - absent; c common species; r rare species.

4. Conclusions

To date, an extensive assessment on the seaweed diversity in the study area has not been reported. Thus, this research was a preliminary study for Merambong Island, Johor, Malaysia. In addition to the physicochemical data of the coastal area of Peninsular Malaysia, a high diversity of seaweeds was recorded.

Acknowledgements

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