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Seasonal variation in the occurrence and abundance of mangrove macroalgae in a Malaysian estuary

Md. Masum BILLAH[a,b], Abu Hena Mustafa KAMAL[a], Mohd Hanafi Bin IDRIS[a] & Johan Bin ISMAIL[a]*

[a]*Faculty of Agriculture and Food Sciences, Department of Animal Science and Fishery, University Putra Malaysia Campus Bintulu, Bintulu-97008, Sarawak, Malaysia*

[b]*Education and Research Center for Marine Resources and Environment, Faculty of Fisheries, Kagoshima University, 50-20 Shimoarata 4-Chome, Kagoshima 890-0056, Japan*

Abstract – Mangrove macroalgae produce substantial proportion of biomass, which contributes to the coastal ecosystems. Relatively less is known for the seasonal variation in the occurrence and biomass of mangrove associated macroalgae. Consequently**,** mangrove macroalgae epiphytic on the pneumatophores of *Avicennia marina* (Forsk.) Vierh., were sampled from the Miri estuary of Sarawak during the four seasons of Malaysia namely southwest monsoon, northeast monsoon, and two inter-monsoons to elucidate seasonal variation in the occurrence and biomass production of macroalgae. Over the sample period, 11 species of mangrove macroalgae were identified from 6 genera. Six of these species such as *Caloglossa leprieurii* (Montagne) J.Agardh*, C. adhaerens* R.J.King & Puttock*, C. stipitata* E.Post*, C. ogasawaraensis* Okamura*, Bostrychia kelanensis* Grunow and *Dictyota* sp. were found to be common in each sample time. Considering four seasonal samples, maximum frequency of occurrence was observed for *C. ogasawaraensis* (66 ± 10%) and maximum biomass was observed for *B. kelanensis* (248 ± 95 g m^{-2}). Marked seasonal variations were observed in the frequencies of occurrence and the biomass for the most of the dominant macroalgal species. To the best of our knowledge this is the first time to report the seasonal pattern data for occurrence and abundance of macroalgae from the mangrove systems of Malaysia.

Mangrove macroalgae / Pneumatophores / Seasonal distribution / Sarawak / Malaysia

INTRODUCTION

Mangroves grow on tropical and subtropical protected coasts (Hoque *et al*., 2015a). Mangrove forests are distributed in almost 124 countries, covering an area of about 1% of the world (Saenger, 2002). Mangroves support distinct macroalgal assemblages as epibionts in the intertidal and subtidal portion of the tree such as dead branches, prop roots, pneumatophores, branches and roots (Dawes *et al*., 1999;

* Corresponding author: k4302867@kadai.jp; masum_imsf07@yahoo.com

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Zhang *et al*., 2014). Some of the invertebrate communities associated with mangrove macroalgal mats have been reported to feed on algae and some of them may also have symbiotic relationships with algae (Mejia *et al*., 2012). Macroalgae associated with mangroves may provide carbon to the primary consumers in the aquatic food web (Koch & Madden, 2001) making them a substantial contributor in the marine ecosystems (Stoner &Zimmerman, 1988). It has been shown that the total standing crop of epiphytic algae in Laguna Joyuda, Puerto Rico is nearly equal to the annual litter production of *Rhizophora mangle* (Rodriguez & Stoner, 1990). Studies have shown that mangrove associated algae such as *Caloglossa leprieurii*, *Catenella nipae*, *Bostrychia moritziana* and *B. tenella* can be used as pottential biomonitor organisms to detect the time integrated level of heavy metal in some Australian estuaries (Melville & Pulkownik, 2007a).

Malaysia has significant proportion of mangroves (577, 500 ha; Jusoff, 2013), that contributes about 4% of the world mangroves and placed at the 6th position in terms of area coverage (FAO, 2007). There are 38 true mangroves, 57 semi-mangrove plants and 9 mangrove associate plant species have been reported from Malaysian mangrove systems (Japar, 1994). Different ecological aspects of Malaysian mangrove forests have extensively been investigated including standing biomass, nutrient flux, litter dynamics (Gong *et al*., 1984; Hossain, 2004; Hoque *et al.,* 2015a) and fisheries production (Hoque *et al.,* 2015b). However, the epibiont floral communities associated with mangroves have received only limited attention to date. Few studies only documented the species composition of mangrove macroalgae (Aikanathan & Sasekumar, 1994; Khatib & Rosli, 2015). It is noteworthy that, mangrove macroalgae have been collected from many geographic regions including Malaysia for further in depth studies such as evolutionary relationships of the macroalgal genus *Caloglossa* (Kamiya *et al*., 2003); cryptic diversity and biogeography of the macroalgal species *Caloglossa ogasawaraensis* (Kamiya & West, 2014) and gall structure in the genus *Bostrychia* (West *et al.,* 2013).

A great deal of studies have been undertaken to report the species composition of mangrove associated macroalgae on different tropical and subtropical coasts, including those of India (Nedumaran & Perumal, 2009), Pakistan (Saifullah & Ahmed, 2007), Brazil (Philips *et al*., 1996;Alves & Fernandes, 2012), Australia (Davey & Woeklering, 1985; King & Puttock, 1994), Egypt (El-Sharouny *et al*., 2001), South Africa (Philips *et al*., 1994)and China (Zhang *et al.,* 2014). Some studies have also been documented the vertical distribution of mangrove macroalgae (Melville *et al*., 2005; Melville & Pulkownik, 2007b). Further, influence of hydrological factors in the distribution of mangrove macroalgae is documented for some mangrove systems (Davey & Woelkerling, 1985; Steinke & Naidoo, 1990; Yokoya *et al*., 1999; Alves & Fernandes, 2012); these studies report that macroalgal assemblages are markedly influenced by hydrological factors such as pH, salinity and turbidity.

Relatively less is known for the seasonal distribution of mangrove macroalgae (Yokoya *et al.,* 1999; Zhang *et al.,* 2014). In Malaysia in particular, virtually no data exist for the seasonal distribution of mangrove macroalgae. Consequently, the present study investigated the seasonal variation in the occurrence and biomass production of mangrove macroalgae from the Miri estuary, Sarawak, Malaysia. We carried out the present study to contribute to the overall ecological knowledge of the epiphytic macroalgal mats on mangroves.

MATERIALS AND METHODS

Study site

Miri River is approximately 45 km long having a river basin of 582 km^2 flowing west ward from the catchment area. The River crosses Miri town and finally reach the South China Sea. The Miri River Estuary (N 04° 24’ 15.8” and E 113° 59’ 20.1”) has small fringes of mangrove (Fig. 1). The average monthly rainfall and temperature are reported as 316 mm and 28°C, respectively in the studied area (Meteorological Department, Niah Forest Research Station, Miri, Sarawak, Malaysia).

The description of the study site has been well documented in the literature of Billah (2015). Briefly, a narrow fringe of mangroves is located up to around 3 km upstream from the mouth of the Miri Estuary. Within this mangrove Estuary, a total of 6 mangrove species *Avicennia marina, Xylocarpus granatum, Rhizopora apiculata, Nypa fruticans, Sonneratia* sp.and *Bruguiera* sp. have been reported. All these species (except *A. marina* and *R. apiculata*) show very scattered in distributions. The average height of *A. marina* has been reported as 10 m. Density of pneumatophores for this species has been reported between 116 and 176 pneumatophores m^{-2}, with an average height of 9.6 cm in the study site. Miri estuarine area is characterized with higher proportion of sand (66-72%) compared to silt (20-31%) and clay (1-5%).

Sample collection

Malaysian climate is characterized with two monsoon seasons comprising southwest monsoon (during late May to September), northeast monsoon (during

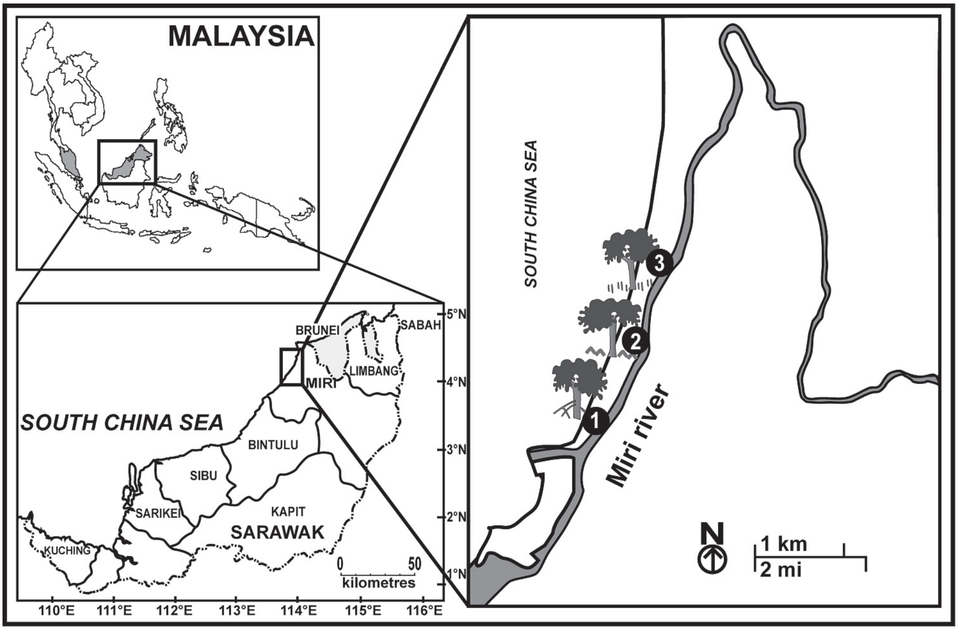


Fig. 1. The study area location showing the sampling plots (1, 2, 3) in the Miri estuary, Sarawak, Malaysia.

November to March) and two inter-monsoon seasons (October and April) (Malaysian Meteorological Department). Macroalgal samples were collected seasonally on September, 2013 (southwest monsoon), October, 2013 (intermonsoon), February, 2014 (northeast monsoon) and April, 2014 (intermonsoon). Three (3) 5×5 m^2 permanent plots were selected at 1 km interval from the mouth of the estuary to the upper reach as long as mangrove fringe prevails (approximately 3 km from the river mouth) and marked as P1, P2 and P3 (Fig. 1). Since only *A. marina* was found to be common in each of the permanent plot, therefore we only examined the pneumatophores of *A. marina* as epiphytic substrates of macroalgae. In this study, due to relatively less (~ 5 m) width of the pneumatophores fringes, 5 pneumatophores were randomly harvested irrespective of their occurrence in tidal gradient (front, middle and back intertidal zones) from each plot. A total of sixty pneumatophores were harvested during course of study. Pneumatophores were cut in the mudline by a clipper and kept in a zip lock plastic, which were then transported to laboratories inside an icebox. Pneumatophores were kept in a chiller (4°C) until further activities.

In-situ hydrological data such as pH, temperature (°C), salinity, turbidity (NTU), Dissolved Oxygen (DO, mg l^{-1}), Total Dissolved Solids (TDS, g l^{-1}) were recorded in estuarine surface water with three replicates adjacent to each permanent plot using multi-parameter device *TOA-DKK* (Model WQC-24). The estuarine surface water samples were collected for hydrochemical data analyses by previously HNO_3 washed polyethylene bottle with three replicates. These samples were kept in icebox and immediately brought to the laboratory. All the samples were collected during low tide.

Laboratory analysis

The length and radius of the pneumatophores were carefully measured by a caliper. The surface area of the pneumatophores was calculated as πdh; where, π = constant, d = radius of the pneumatophores, h = length of the pneumatophores (Steinke and Naidoo, 1990). Frequency of occurrence (F) of particular algae was calculated as the ratio of number of pneumatophores on which a particular algae occurred (ΣN) and total number of pneumatophores studied (N), $F = \Sigma N/N$ (Phillips *et al*., 1996). Algal materials were carefully scrapped by a stainless knife into the petridishes and identified up to species level under a dissecting microscope using suitable taxonomic literatures (e.g., Pedroche *et al*., 1995; West *et al*., 2008). Macroalgal samples were then dried overnight (70°C) and weighed. The biomass (dry weight) of macroalgae was expressed as g m^{-2}; based on previously determined surface area of pneumatophores.

Milipore Filtering System were applied to filter the estuarine water, dissolve inorganic ammonium (mg l^{-1}), nitrate (mg l^{-1}) and phosphate (mg l^{-1}) were measured following Weatherburn (1967), Kitamura *et al*. (1982) and Parsons *et al*. (1984), respectively. Fe concentrations (μg l^{-1}) of water samples were measured in previously filtered acidified water samples following Cenci and Martin (2004) using an Air-Acetylene Perkin-Elmer™ flame Atomic Absorption Spectrophotometer (AAS) Model Analyst 800.

Data analysis

The one-way analysis of variance (ANOVA) was used to determine if there were any significant differences between quantitative variables among the seasons.

Prior to this, each variable was tested for normality (Shapiro-Wilk test) and homogeneity (Levene test) and if needed, the data were transformed and rechecked to confirm that transformation enhanced their distribution. There were only few variables such as turbidity and NH_4^+ were found to meet the criterion of normality and homogeneity. The data which did not exhibit normality and homogeneity; were subjected to Kruskal Wallis test (a non parametric test; Kim *et al*., 2013). ANOVA and Kruskal Wallis test were carried out by SAS (statistical analysis system; version 9.1).

RESULTS

Hydrological characteristics

The recorded hydrological factors (range; pH, 6.34-7.31; surface water temperature, 28.06-31.30°C; salinity, 8.40-31.30; TDS, 12.84-48.90 g l^{-1} ; DO, 2.71-5.50 mg l^{-1}; turbidity, 21.3-46.2 NTU; NO_3^-, 0.04-0.16 mg l^{-1}, NH_4^+, 0.55-0.63 mg l^{-1}, PO_4^{2-}, 0.02-0.13 mg l^{-1} and Fe 0.19–1.63 µg l^{-1}) are shown in Table 1. All the hydrological factors measured in this study (Table 1), showed highly significant seasonal (df = 3) variations such as pH ($H = 7.78$, $P = 0.05$), temperature ($H = 19.70$, $P = 0.0002$), turbidity ($F = 1172.79$, $P = 0.0001$), TDS ($H = 19.30$, $P = 0.0002$), DO ($H = 16.30$, $P = 0.001$), NO_3^- ($H = 13.22$, $P = 0.004$), salinity ($H = 19.54$, $P = .0001$), Fe ($H = 14.26$, $P = 0.002$), and PO_4^{2-} ($H = 12.00$, $P = 0.007$), except NH_4^+ ($F = 0.31$, $P = 0.82$).

Species compositions

A total of 11 species of macroalgae were found as epiphytes on pneumatophores in the study area; 8 species of algae belong to Division Rodophyta, 2 species belong to the Division Chlorophyta and only one species from the Division Phaeophyta (Table 2). Macroalgal species such as *Caloglassa leprieurii*, *C. adhaerens*, *C. stipitata*, *C. ogasawaraensis*, *Bostrychia kelanensis* and *Dictyota* sp., were found to be common in each sample time.

Algal frequency and biomass

Frequency and biomass of dominant macroalgal species in each season are presented in Table 3.

Table 1. Hydrological factors recorded in the Miri estuary during the present study (values are mean ± se; n = n 9 for each sample time; Sep 13, September 2013, Oct 13, October 2013, Feb 14, October 2014, Apr 14, April 2014)

Sample time	*pH*	*Temp. (°C)*	*Salinity*	*TDS* ($g\ l^{-1}$)	*DO* ($mg\ l^{-1}$)	*Turbidity (NTU)*	NO_3^- ($mg\ l^{-1}$)	NH_4^+ ($mg\ l^{-1}$)	$P0_4^{2-}$ ($mg\ l^{-1}$)	*Fe* ($\mu g\ l^{-1}$)
Sep 13	6.59 ± 0.12	30.61 ± 0.07	17.23 ± 1.0	26.71 ± 1.81	2.45 ± 1.00	34.57 ± 1.88	0.16 ± 0.02	0.60 ± 0.07	0.13 ± 0.06	0.19 ± 0.01
Oct 13	6.34 ± 0.00	28.41 ± 0.03	8.4 ± 0.01	12.84 ± 0.05	2.71 ± 0.50	42.7 ± 0.24	0.15 ± 0.01	0.63 ± 0.07	0.13 ± 0.03	0.20 ± 0.05
Feb 14	7.15 ± 0.02	28.06 ± 0.32	18.3 ± 3.86	30.66 ± .15	5.50 ± 0.80	46.20 ± 2.35	0.15 ± 0.00	0.60 ± 0.06	0.13 ± 0.07	1.63 ± 0.15
Apr 14	7.31 ± 0.04	31.3 ± 0.06	31.3 ± 0.14	48.9 ± 0.29	4.13 ± 0.50	21.3 ± 1.76	0.04 ± 0.00	0.55 ± 0.11	0.02 ± 0.00	1.63 ± 0.02

*Caloglassa leprieurii*and *C. ogasawaraensis* were found at similar frequencies and abundance. Relatively less frequency and biomass data were reported for *Dictyota* sp.. Considering four seasonal samples the comparison of the observed frequency of the occurrence and biomass among dominant macroalgal species during the course of study are shown in Figs 2 and 3, respectively. During the course of study the order of the frequency of occurrence for dominant macroalgal species was *C. ogasawaraensis* > *C. leprieurii*> *C. stipitata* > *B. kelanensis* > *C. adhaerens* >

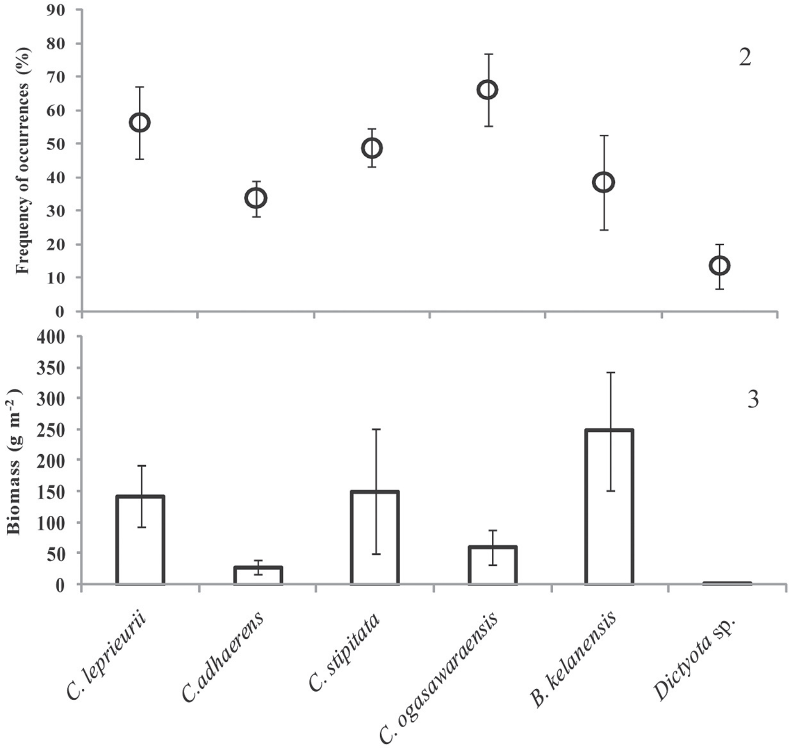
Table 2. Division, species name and abbreviation for the species recorded from different plots (1, 2 and 3) in the Miri estuary, Sarawak, Malaysia. (Sep 13, September 2013; Oct 13, October 2013; Feb 14, February 2014; Apr 14, April 2014)

	Sep 13			*Oct 13*			*Feb 14*			*Apr 14*		
Species name	*1*	*2*	*3*	*1*	*2*	*3*	*1*	*2*	*3*	*1*	*2*	*3*
Rhodophyta												
Caloglossa leprieurii (Montagne) J. Agardh	+	+	+	+	+	–	+	+	+	+	+	+
Caloglossa adhaerens R.J. King & Puttock	+	–	–	+	+	–	+	+	–	+	+	–
Caloglossa stipitata E.Post	+	+	+	+	+	+	+	+	+	–	+	–
Caloglossa ogasawaraensis Okamura	–	+	+	+	+	+	+	+	+	+	+	+
Bostrychia kelanensis Grunow	+	+	+	+	–	+	+	–	–	+	+	–
Bostrychia anomala J.A.West, S.Loiseaux de Gor and G.C.Zuccarello	–	–	+	+	+	+	+	–	–	–	–	–
Bostrychia radicans Montagne	–	–	–	+	–	+	–	–	–	–	–	–
Hypnea sp.	–	–	+	–	–	+	–	–	+	–	–	–
Chlorophyta												
Chaetomorpha sp.	+	–	–	–	–	–	+	–	–	+	+	+
Ulva intestinalis Linnaeus	–	–	–	–	–	–	–	–	–	–	+	+
Phaeophyta												
Dictyota sp.	–	+	+	–	–	+	–	–	+	–	–	+

Table 3. Biomass (g m^{-2} of pneumatophore surface area) and frequency of occurrence (%) for common seasonal macroalgal species during each sample time from the Miri estuary, Sarawak, Malaysia. Values are mean ± se across sample time; n = 15. (Biom = biomass; Freq = frequency; T = trace amount; Sep 13, September 2013; Oct 13, October 2013; Feb 14, February 2014; Apr 14, April 2014)

	Sep 13		*Oct 13*		*Feb 14*		*Apr 14*	
	Biom.	*Freq*	*Biom*	*Freq*	*Biom*	*Freq*	*Biom*	*Freq*
Caloglossa leprieurii	7 ± 1	23 ± 10	88 ± 17	43 ± 19	226 ± 41	63 ± 19	251 ± 33	97 ± 3
Caloglossa adhaerens	2 ± 0	33 ± 19	61 ± 4	23 ± 12	31 ± 5	30 ± 14	61 ± 9	48 ± 15
Caloglossa stipitata	12 ± 2	72 ± 10	520 ± 76	50 ± 15	71 ± 11	63 ± 16	T	10 ± 6
Caloglossa ogasawaraensis	73 ± 13	43 ± 15	3 ± 1	53 ± 11	132 ± 20	90 ± 4	35 ± 6	78 ± 9
Bostrychia kelanensis	34 ± 6	73 ± 11	954 ± 187	50 ± 20	7 ± 1	10 ± 4	T	22 ± 10
Dictyota sp.	10 ± 2	31 ± 11	5 ± 1	17 ± 12	T	3 ± 3	T	3 ± 3

Dictyota sp.. Maximum frequency was observed for *C. ogasawaraensis* (66 ± 10%) and minimum frequency (13 ± 3%) was observed for *Dictyota* sp. (Fig. 2). Relative to frequency of occurrence significant temporal difference was observed for most of the dominant macroalgal species (except *C. adhaerens,* Table 4).



Figs 2-3. **2.** Frequency of occurrences and **3.** Biomass (g m^{-2} surface area of pneumatophores) for the dominant mangrove macroalgal species from the Miri estuary during the course of study (values are mean ± standard error, n = 60).

Table 4. Kruskal-Wallis test of differences among seasons for frequency of occurrence and biomass of most of the dominant macroalgal taxon from the Miri estuary, Sarawak, Malaysia (df = 3, **P* ≤ 0.05, ***P* ≤ 0.01, ns = not significant at *P* = 0.05)

	Frequency		*Biomass*	
Species	*H*	*P*	*H*	*P*
Caloglossa leprieurii	9.03	*	10.21	**
Caloglossa adhaerens	1.16	ns	2.75	ns
Bostrychia kelanensis	7.43	*	6.83	ns
Caloglossa stipitata	8.68	*	7.65	*
Caloglossa ogasawaraensis	7.83	*	7.93	*
Dictyota sp.	9.46	*	4.57	ns

The order of the biomass for the dominant macroalgal species was *B. kelanensis* > *C. stipitata* > *C. leprieurii* > *C. ogasawaraensis* > *C. adhaerens* > *Dictyota* sp. *B. kelanensis* was found with a maximum biomass (248 ± 95 g m^{-2}) and *Dictyota* sp. was recorded with lowest biomass (3 ± 2 g m^{-2}) (Fig. 3). Further, relative to biomass production macroalgal species such as *C. leprieurii, C. stipitata* and *C. ogasawaraensis* were found to be significantly influenced by temporal variations in the Miri estuary (Table 4).

DISCUSSION

Generally, estuaries are markedly influenced by the quality and quantity of fresh water inflow (Hopkinson & Vallino, 1995). In the Miri estuary, marked seasonal variations (except ammonium) were observed in all hydrological and hydrochemical factors that includes; pH, temperature, salinity, TDS, turbidiy, NO_3^- and Fe concentrations. Seasonality of water characteristics within an estuary is governed by number of factors including fresh water discharge, biogeochemical process, evaporation and alteration of seawater exchange (Mistri *et al*., 2000). In the estuarine environment growth, reproduction and metabolic rate of organisms is highly influenced by the nutrient concentrations. Martins *et al*. (2001), reported that substantial sources of N, P and sediment within an estuary are derived from fresh water input. The observed estuarine hydrological factors such as pH, temperature, salinity, TDS, turbidity, NO_3^- in Miri estuary can be comparable with other estuarine coastal environments of Sarawak, Malaysia (Hoque *et al*., 2015b). Besides the Fe concentrations recorded in the present study (0.19-1.63 μg l^{-1}) was slightly lower than that reported from coastal waters of Sarawak, Malaysia (1.55-5.16 μg l^{-1}, Billah *et al*., 2014).

The recorded mangrove macroalgal species assemblages from the Miri estuary have already been reported from Malaysia (Aikanathan & Sasekumar, 1994; Kamiya *et al*., 2003; West *et al.,* 2013; Kamiya & West, 2014; Khatib & Rosli, 2015) and outside of Malaysia (Pedroche *et al.*, 1995; Yokoya *et al*., 1999; Crona *et al*., 2006; West *et al*., 2008, Alves & Fernandes, 2012). The number of macroalgal species (11) recorded from mangrove systems of the Miri estuary is comparatively higher than those reported from the Parramatta estuary (7 sp., Melville *et al*., 2005) and the Clyde estuary (6 sp., Melville & Pulkownik, 2007b) but comparatively less than those reported from Zhanjiang mangrove systems, in China (36 sp., Zhang *et al*., 2014). However, latitudinal gradients must also be considered while these types of comparison are ascertained (Mejia *et al*., 2012). Seven of eleven macroalgae species recorded from the Miri estuary were either in the *Caloglossa* or in the *Bostrychia* genera (Table 2). Previous studies have been confirmed that *Caloglossa-Bostrychia* association is a characteristic of the mangrove ecosystems (Philips *et al*., 1996; Zhang *et al*., 2014). Though not frequent, only few macroalgae species (4 sp.) were found to be in other genera such as *Ulva intestinalis, Hypnea* sp. and *Dictyota* sp. which were observed during this study. These species are however extensively found in the intertidal rocky shore of Sarawak, Malaysia (Wong *et al*., 2010).

This study recorded algae from the three Divisions namely Rhodophyta, Phaeophyta and Chlorophyta (Table 2), suggesting that the Miri estuary is relatively unpolluted in terms of nutrient concentrations. The presence of red, brown and green algae is generally found under unpolluted conditions while presence of filamentous green algae indicates highly eutrophic status of a site (Peckol *et al*., 1994; Peckol and Rivers, 1995). Periodic presence of opportunistic macroalgae such *Chaetomorpha* sp. and *U. intestinalis* suggest sudden enrichment of N and P loading in the Miri estuary (Vogt &Schramm, 1991; Fletcher, 1996).

Comparison of the frequency of occurrence and the biomass of mangrove macroalgae with results reported from other studies is difficult because of the differences of methodology adopted in other studies. Numerous factors have already been investigated that determine the presence or absence and biomass of mangrove macroalgal species. The factors include desiccation tolerance, light availability, turbidity, salinity preference, tidal level, wave action, immersion period and amount of shading (Tanaka & Chihara, 1987; Mann & Steinke, 1988; Phillips *et al*., 1996; Yokoya *et al*., 1999; El-Sharouny *et al*., 2001).

Over the study period, there were significant seasonal differences in the frequency of occurrence and the biomass production for most of the dominant macroalgal species (Table 4). This could probably be due to the significant variations of most water nutrients especially NO_3^- and PO_4^{2-} over the sample period (Peckol *et al*., 1994). Studies confirmed that nutrient availability in different seasons may contribute in the seasonal changes of algal biomass (Valiela *et al*., 1997). Middelboe *et al.* (1998) examined macroalgal assemblages of 26 estuaries in Denmark and speculated that algal species richness is highly influenced by some abiotic factors including nutrient concentrations. Besides, in a laboratory experiment it has been found that specific growth rates of mangrove macroalgae such as *B. moritziana* and *C. leprieurii* are decreased due to limiting concentrations of nitrate and phosphate (Ryder *et al.,* 1999). Moreover, there is evidence that enormous siltation load associated with meteorological disturbances (e.g., flood, cyclones) have been influenced the mangrove macroalgal biomass in the Saint Lucia estuary, South Africa (Steinke & Naidoo, 1990). The marked differences of TDS and turbidity in the Miri estuary over the sample period may also be attributed for these seasonal variations of macroalgal assemblages.

In this study few macroalgal species such as *C. adhaerens* (relative to frequency of occurrence) and *B. kelanensis, C. adhaerens* and *Dictyota* sp. (relative to biomass production) did not show seasonality (Table 4). Some studies have already been documented no significant seasonal variation in the occurrence and biomass production of macroalgae from the mangrove systems of Australia (Melville *et al.*, 2005; Melville & Pulkownik, 2007b). This can be explained by the fact that these species were more related to attaching substratum (pneumatophores) rather than hydrological factors including nutrients (Nedwell *et al*., 2002). Besides, generally algae are long lived and capable of storing nutrients to use it during period of nutrient limitations (Hein *et al*., 1995).

In conclusion, studies of seasonal pattern for occurrence and abundance of mangrove macroalgae are sparse. To the best of our knowledge this is the first time to report the seasonal pattern in the occurrence and abundance of mangrove macroalgae from Malaysian mangrove systems. The examination of the occurrence and abundance of mangrove macroalgae revealed significant seasonal variation for most of the dominant macroalgal species. Besides, the study also discussed some important hydrological factors that can influence the occurrence and abundance of mangrove macroalgae. The data presented here may prove useful in experimental design of future research aimed at investigating suitable macroalgal bioindicator species from mangrove systems elsewhere especially in Malaysia (Melville *et al.*, 2005).

Compliance with Ethical Standards The authors declare that they have no conflict of interest.

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