Seasonal growth rate of Sargassum *species at Teluk Kemang, Port Dickson, Malaysia*

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Abstract The seasonal growth rates of three *Sargassum* species were studied along two reef flats of Teluk Kemang, located at Port Dickson, Malaysia from September 2009 to September 2010. Systematic quadrat and line transects were sampled monthly. Nondestructive sampling was conducted, whereby *Sargassum* plants were tagged and monitored for a 13-month period. The majority of the tagged *Sargassum* samples belonged to lower length classes (<200 mm), especially in 0–99 mm (*Sargassum polycystum*, 64.20 %; *Sargassum binderi*, 68.29 %; *Sargassum siliquosum*, 56.80 %). Analysis of the monthly mean thallus length (MTL) revealed a bimodal pattern in growth rates, with two periods of high growth rates (January–February 2010 and June–July 2010) and two periods of higher degenerative rates (April 2010 and September 2010). The highest growth rates were recorded in February 2010 (4.08 mm day^{-1}) for *S. siliquosum*, and in June for *S. polycystum* (2.54 mm day^{-1}) and *S. binderi* (1.89 mm day^{-1}). Redundancy analysis (RDA) was employed to test for the overall correlation between monthly variation in MTL and the environmental parameters measured; *S. binderi* was correlated with ambient temperature ($r = 0.5395$), while *S. siliquosum* was correlated with seawater salinity ($r = 0.5419$) and ammonia ($r = -0.4603$). This study reviews the seasonality of *Sargassum* species on two reefs of Teluk Kemang and their correlation with the selected environmental parameters.

Keywords Growth rate · Length classes · *Sargassum* · Phaeophyceae · Port Dickson · RDA

Introduction

The genus of *Sargassum* (Phaeophyceae) dominates the benthic reefs of tropical (Ang 2006) and temperate regions (Hwang et al. 2006; Komatsu et al. 2007). It has been estimated that there are roughly 10,000 different species of seaweeds recorded (Guiry and Guiry 2011), of which an estimated 400 species belong to the genus *Sargassum* (Wong and Phang 2004). In Teluk Kemang, three specific species are found abundantly along the reef flats, i.e., *Sargassum polycystum* C. A. Agardh, *Sargassum binderi* Sonder ex J. G. Agardh, and *Sargassum siliquosum* J. G. Agardh.

Members of the genus *Sargassum*, such as *Sargassum muticum* Yendo (Fensholt) may be relatively easy to cultivate, due to high growth rate, long lifespan and ability to reproduce within the first year (Kraan 2008). In addition, members of the genus *Sargassum* generally possess high nutritional value that make many of the species such as *S. polycystum and Sargassum vulgare* C. Agardh beneficial for human consumption (Marinho-Soriano et al. 2006; Matanjun et al. 2009). Most of the members contain high concentration of macronutrients that serve as additives to fertilisers (Demir et al. 2006), polyunsaturated fatty acids that are useful in cosmetic products (Zubia et al. 2008), and many industrially important polysaccharides, namely alginate, fucoidans, mannitol, and phlorotannins (Zubia et al. 2008).

Phenological studies have shown that members of the genus *Sargassum* exhibit seasonal cycles of growth, reproduction, senescence, and dieback (Ang 2006). De Wreede (1976) generalised that in temperate regions, members of the genus *Sargassum* are most abundant during the warmest part of the year, while in tropical regions during the coolest part. However, this may vary among reef ecosystems of high complexity. For instance, eight species of *Sargassum*,

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namely *Sargassum angustifolium* (Turn.) Ag., *Sargassum enerve* Ag., *Sargassum fusiforme* (Harv.) Setch., *Sargassum glaucescens* J. Ag., *Sargassum hemiphyllum* (Turn.) Ag., *Sargassum henslowianum* C. Ag., *Sargassum patens* Ag. and *Sargassum siliquastrum* (Turn.) Ag., studied in tropical Hong Kong grew slowest during summer but began to grow fast during autumn, climaxing during the coldest months of January to March (Ang 2006). A study conducted in the tropical waters of Cape Rachado in Malaysia proved otherwise, whereby the abundance of *Sargassum baccularia* (Mertens) C. Agardh and *S. binderi* peaked during the hot and dry inter-monsoon seasons but declined during cold and rainy monsoon seasons (Phang 1995).

The growth of seaweeds responded to a wide variety of ever-changing biotic and physical abiotic factors (Kraufvelin et al. 2009). Thus, seasonal changes in abiotic factors such as temperature, salinity, pH, nutrients, water motion, etc. drive annual growth cycles of *Sargassum*. Temperature affects seaweed morphology and its geographical distribution (Chung et al. 2007), while regulating its reproduction (Agrawal 2009). Studies conducted on the coral reefs of southern Taiwan showed that the effects of water temperature on abundance was positive for *S. siliquosum* but negative for *S. polycystum* (Hwang et al. 2004). Generally, members of the genus *Sargassum* can survive in a wide range of water salinities, but Steen (2004) found that growth of the invasive *S. muticum* reached an optimum at 34 ‰. Nishihara and Terada (2010) stated that increase in surrounding nutrient supply lead to an increase in physiological processes, such as nutrient uptake and photosynthesis.

Mariculturists depend on local phenological studies to determine the ideal periods for seasonal harvesting. For instance, harvest of *Sargassum* on the southern coasts of India takes place from August to January (Khan and Satam 2003). Despite all its benefits and natural abundance on the reefs of Malaysia, local cultivation of *Sargassum* is almost unheard of. The objectives of this study are to determine the seasonality of *Sargassum* and its growth rate, as well as to correlate growth with environmental parameters.

Materials and methods

Sampling site: Teluk Kemang, Port Dickson

The beach of Teluk Kemang at Port Dickson (2°26′ N, 101°51′ E) is located at the west coast of Peninsular Malaysia, facing the Straits of Malacca. Two particular patches of reef flats located roughly 80 m from shore and 80 m apart from one another were chosen as study sites. Both the reef flats are measuring up to 60 m in length. The study sites are fairly secluded and a vast variety of seaweed species can be found growing on the reefs. Despite being under conservation by the Department of Fisheries, Malaysia, a hotel directly facing the beach was seen constantly releasing effluent wastes into the sea. Throughout the 13-month study, several developments took place to make this area as a tourist attraction, such as pavement of tarred roads and parking lots, as well as construction of concrete-stilted balconies on the shore.

Sampling method

Field trips were conducted on a monthly basis to Teluk Kemang from September 2009 to September 2010. Systematic quadrat and line transect methods were employed at the two coral reef flats, whereby a 50-m line transect was laid on the left and right reef, parallel to the shoreline. Along each line, a total of five quadrats with 0.25 m^2 (0.5 m × 0.5 m) were placed sequentially at every 10-m interval, beginning from 0 m extending to 50 m. The exact coordinate of each permanent quadrat was recorded by GPS for easy location of the exact same quadrats in subsequent months. Within each quadrat, nondestructive sampling was applied whereby all *Sargassum* species were identified morphologically based on descriptions by Trono (1997). These were tagged at the base using plastic cable ties, bearing labelled Dymo embossing tapes. Every month, the thallus lengths of all tagged samples were measured from the base to the tip of the longest lateral branch, and the presence of receptacles was noted. Appearance of new recruits within the quadrats was given new tags, while lost tags were noted.

Environmental parameters

Seawater temperature and salinity were measured in situ using a portable DO metre (HANNA, HI 9143) and handheld refractometer (Atago, Master-S/Millα). Seawater samples were collected and kept in an ice box for later analysis (within 3 h). In the laboratory, pH of sampled seawater was measured using a standard pH metre (Sartorius, PB-11). Nutrients such as nitrate, ammonia and phosphate were measured using a portable spectrophotometer (Hach, DR 2800) according to manufacturer's instructions. Meteorological data such as monthly rainfall, mean ambient air temperature and mean solar radiation were obtained from the Malaysian Meteorological Department, Petaling Jaya.

Data analysis

The thallus length measurements of each species were averaged each month to obtain mean thallus length (MTL). Absolute growth rates (mm day^{-1}) of each species was determined by calculating the differences in the overall thallus length of each population between two consecutive sampling occasions and dividing the results with number of days in between samplings. Percentage fertility was measured by dividing the number of plants bearing receptacles by total number of plants that month. One-way ANOVA was applied to test if there were any significant differences in monthly mean thallus length of each *Sargassum* species. The effects of environmental parameters on *Sargassum* growth were analysed using redundancy analysis (RDA), which is a constrained form of the linear ordination method, using CANOCO Version 4.55.

Results

Length classes

Overall, *S. polycystum*, *S. binderi and S. siliquosum* in Teluk Kemang consisted mostly of smaller sized plants (<200 mm) with a small percentage of larger sized plants. Figures 1, 2 and 3 show that the majority of monthly sample sizes were in the 0–99-mm length class. Of the three species, the thallus lengths of *S. siliquosum* were the most diverse in range (largest thallus 900–999 mm), followed by *S. polycystum* (largest thallus 800–899 mm) and *S. binderi* (largest thallus 500–599 mm).

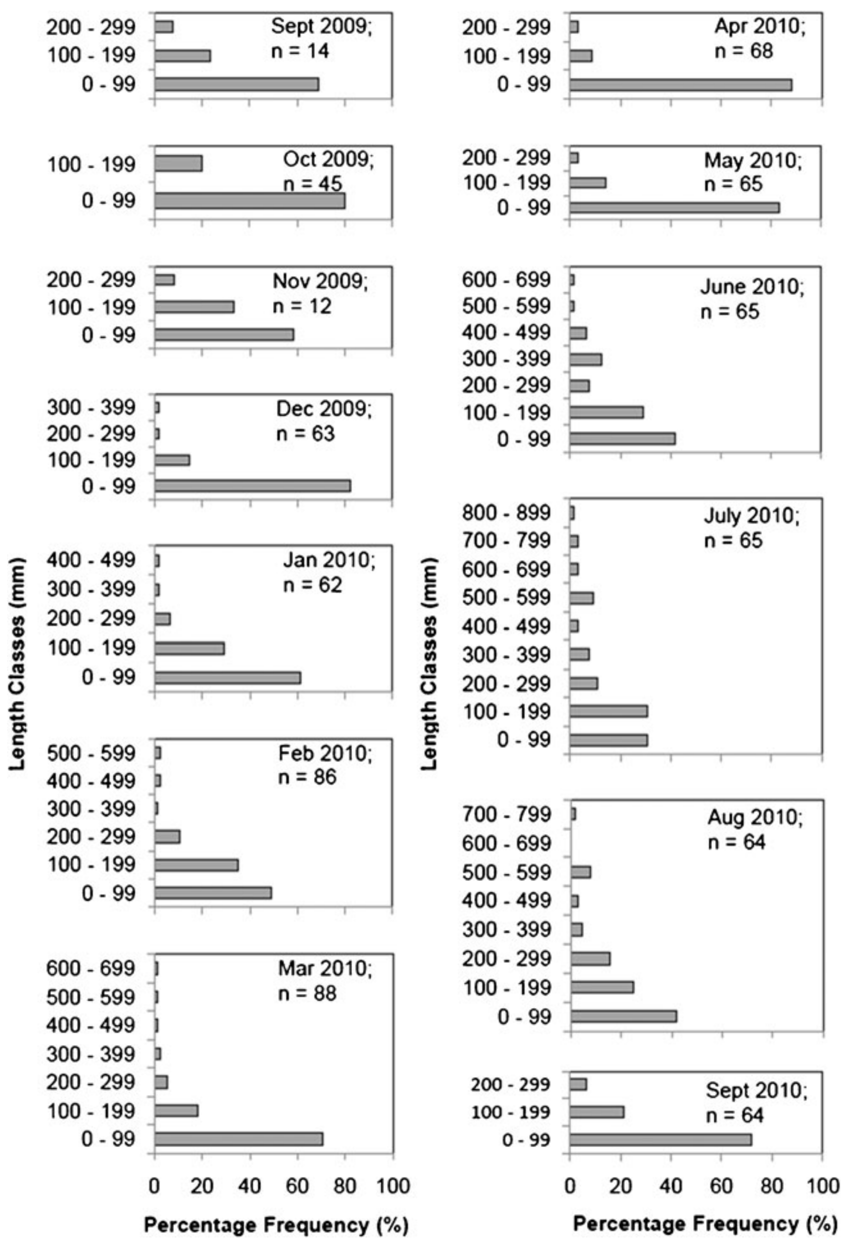

Fig. 1 Monthly length class distribution of *S. polycystum* from September 2009 to September 2010

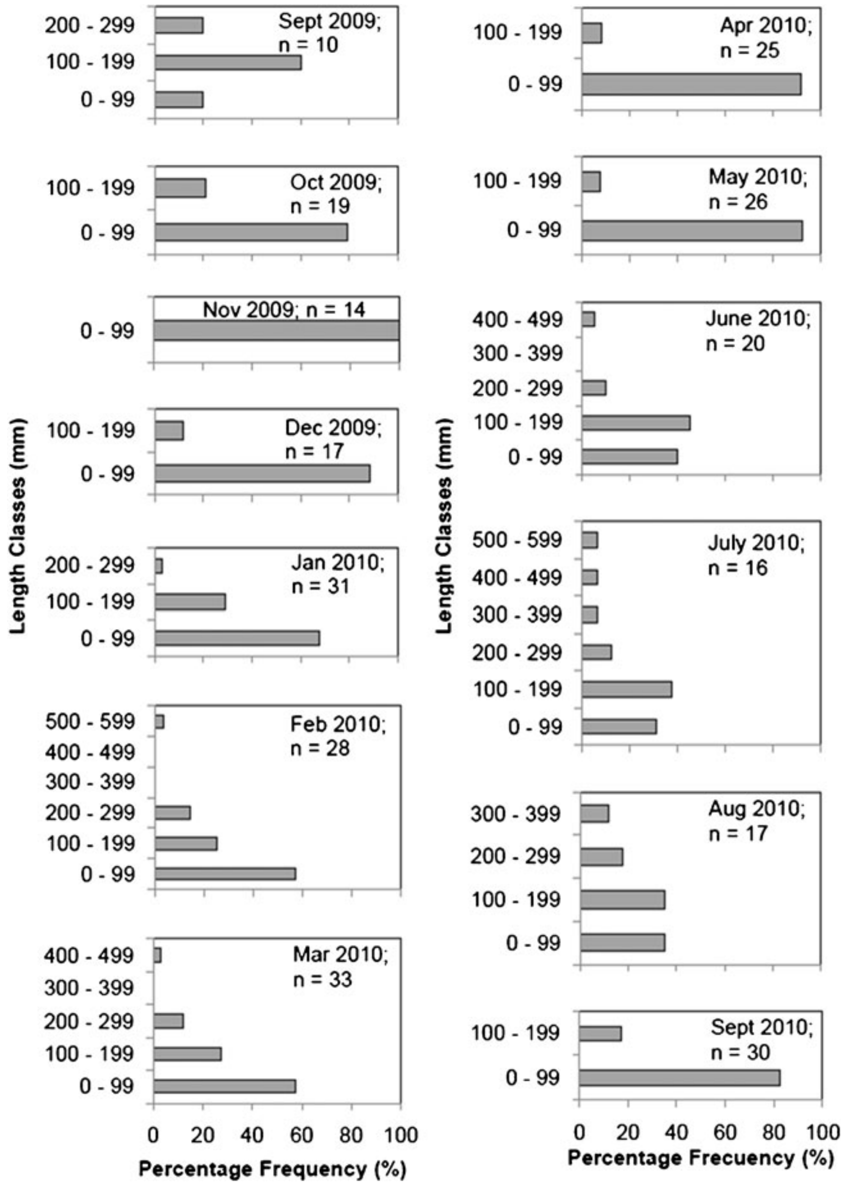

Fig. 2 Monthly length class distribution of *S. binderi* from September 2009 to September 2010

Monthly MTL

A clear pattern in monthly MTL variation was observed for all three species from Fig. 4. One-way ANOVA showed significant differences in monthly MTL variation ($p < 0.01$) for *S. polycystum* ($F = 19.218$), *S. binderi* ($F = 6.601$) and *S. siliquosum* ($F = 13.721$).

Larger plants were measured in September 2009 (*S. polycystum*: MTL = 76.43 mm, largest length class within 200–299 mm; *S. binderi*: MTL = 135.94 mm, largest length class within 200–299 mm; *S. siliquosum*: and MTL = 119.64 mm, largest length class within 500–599 mm), which gradually decreased and increased in MTL for the next few months until February 2010 where MTL peaked (*S. polycystum*: MTL = 127.21 mm, largest length class within 500–599 mm; *S. binderi*: MTL = 121.96 mm, largest length class within 500–599 mm; and *S. siliquosum*: MTL = 223.30 mm, largest length class within 900–999 mm). This was followed by another cycle of gradual decrease in MTL toward the middle of the year and thereafter another increase until July 2010, where MTL were highest for all three species (*S. polycystum*: MTL = 228.62 mm, largest length class within 800–899 mm; *S. binderi*: MTL = 166.88 mm, largest length class within 500–599 mm; and *S. siliquosum*: MTL = 281.14 mm, largest length class within 500–599 mm). MTL then decreased again until September 2010.

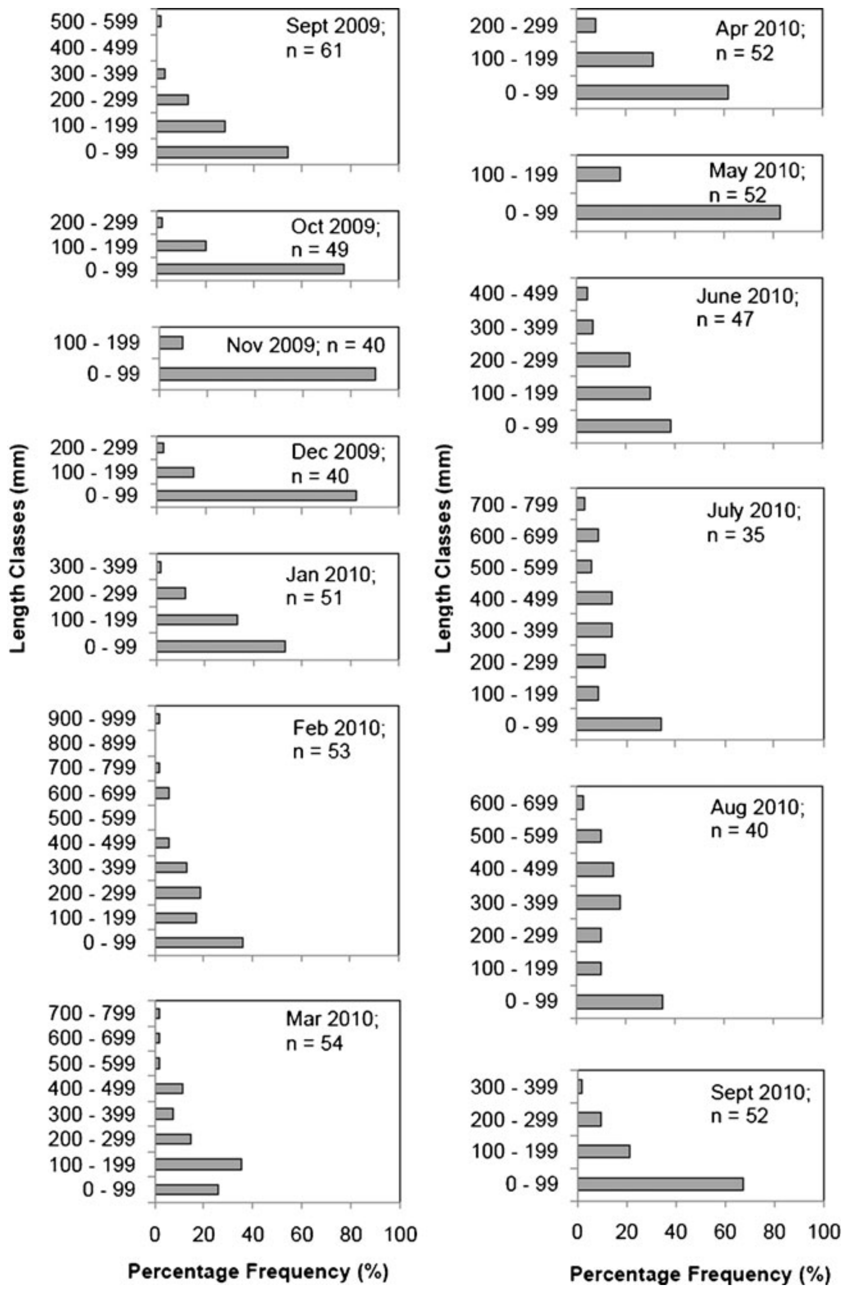

Fig. 3 Monthly length class distribution of *S. siliquosum* from September 2009 to September 2010

Percentage fertility

One-way ANOVA also shows significant differences in monthly percentage fertility for *S. polycystum* ($F = 3.801$; $p = 0.000$), *S. binderi* ($F = 5.062$; $p = 0.000$) and *S. siliquosum* ($F = 11.971$; $p = 0.000$). Figure 4 shows three occasions of peak fertilities for *S. polycystum* (October 2009: 13.33 %; February 2010: 13.95 %; August 2010: 17.19 %), *S. binderi* (September 2009: 50 %; March 2010: 18.18 %; August 2010: 41.18 %) and *S. siliquosum* (September 2009: 27.27 %; March 2010: 35.19 %; August 2010: 50 %).

Growth rate

All three species experienced similar patterns in their growth rates (Fig. 5). From September 2009 to October 2009, tagged samples experienced a degenerative rate. Samples eventually had a peak growth rate in January 2010 (*S. polycystum*, 1.17 mm day^{-1}) and February 2010 (*S. binderi*, 1.54 mm day^{-1}; *S. siliquosum*, 4.08 mm day^{-1}), in which *S. siliquosum* grew at its highest rate. This was followed by one of the lowest degenerative rates in April 2010 (*S. polycystum*, −1.96 mm day^{-1}; *S. binderi*, −2.27 mm day^{-1};

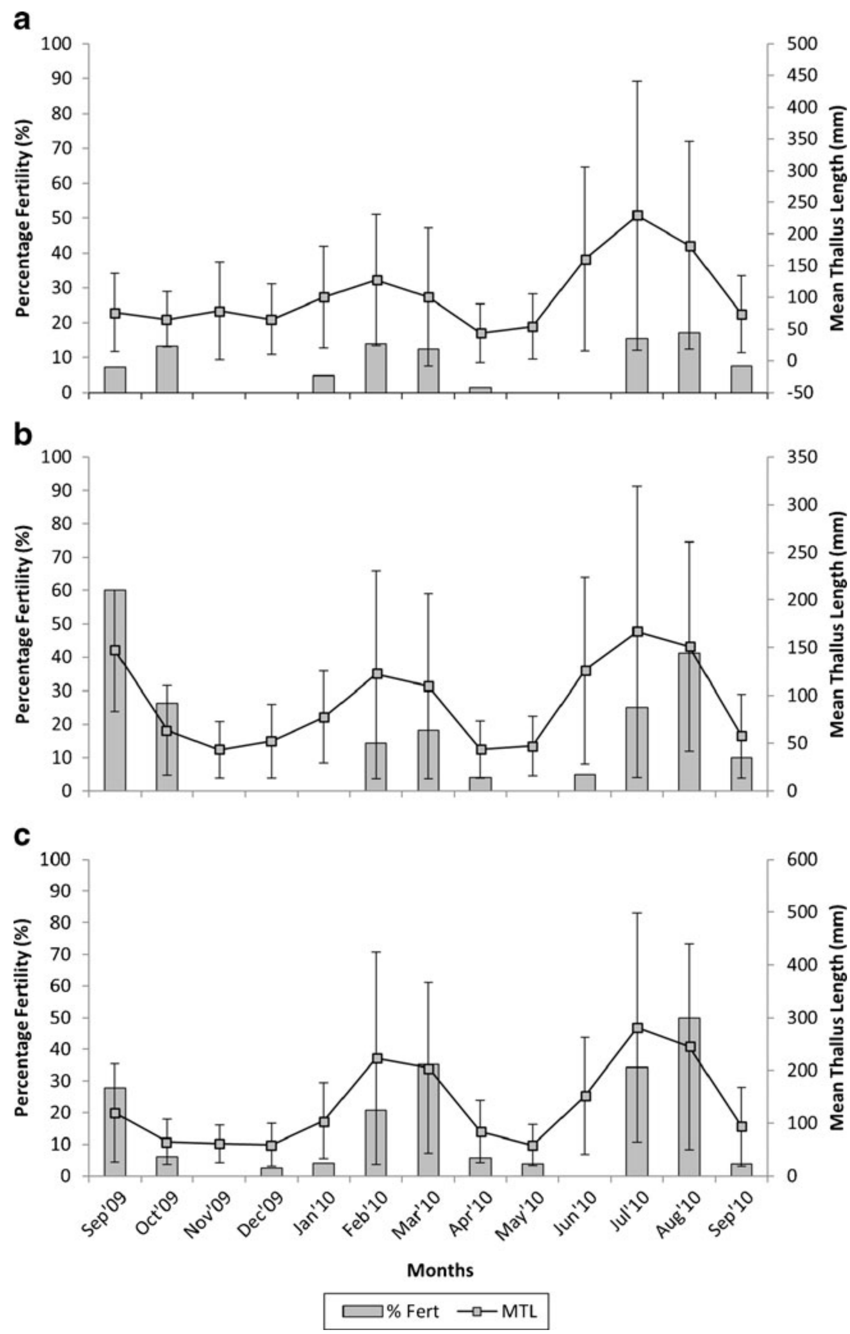

Fig. 4 Monthly mean thallus length (mm ± SD) and percentage fertility (in percentage) from September 2009 to September 2010. **a** *S. polycystum*. **b** *S. binderi*. **c** *S. siliquosum*

and *S. siliquosum*, −4.17 mm day^{-1}). Another peak in growth was observed in June 2010 (*S. polycystum*, 2.54 mm day^{-1}; *S. binderi*, 1.89 mm day^{-1}) and July 2010 (*S. siliquosum*, 3.01 mm day^{-1}), whereby in June 2010, *S. polycystum* and *S. binderi* were growing at their highest rate. After which all species ended in September 2010 with the highest degenerative rate (*S. polycystum*, −3.75 mm day^{-1}; *S. binderi*, −3.23 mm day^{-1}; *S. siliquosum*, −5.22 mm day^{-1}).

Redundancy analysis

Relationship between monthly variations in MTL of tagged samples and environmental variations were illustrated in RDA ordination triplot (Fig. 6). The diagram shows that 91.6 % of the total variance can be explained based on the first two axes (Table 1).

The RDA triplot in Fig. 6 indicates that MTL of *S. polycystum* is positively correlated with nitrate but negatively

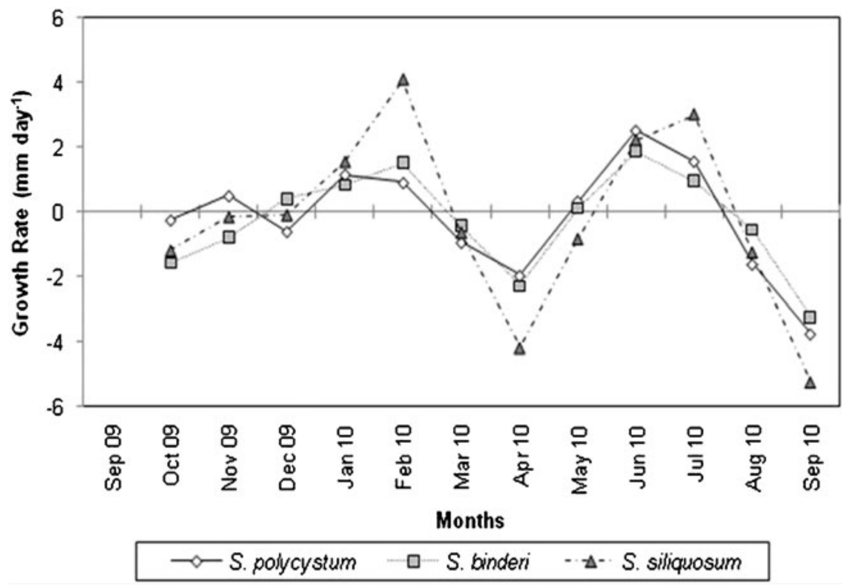

Fig. 5 Monthly growth rate of *Sargassum* species from September 2009 to September 2010

correlated with pH. However, no parameters tested significant from the correlation matrix (Table 2). MTL of *S. binderi* indicated positive correlation with salinity and ambient air temperature, while it was negatively correlated with solar radiation. However, the correlation matrix in Table 2 shows that MTL was significantly correlated only with ambient temperature (r = 0.5395). MTL of *S. siliquosum* indicated positive correlation with salinity and ambient temperature, while it was negatively correlated with ammonia and phosphate.

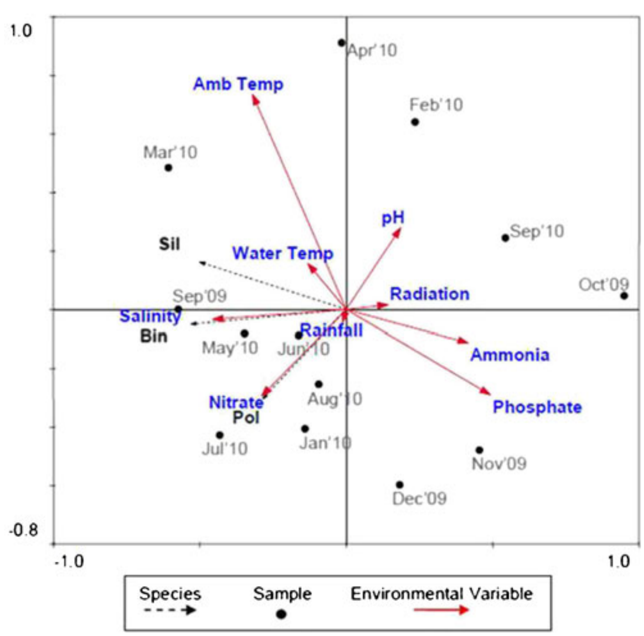

Fig. 6 RDA triplot comparing between monthly mean thallus length of three *Sargassum* species from nondestructive sampling with variation in environmental parameters, with eigenvalues 0.210 and 0.038 for the first two axes. Abbreviations: *S. polycystum* (*Pol*), *S. binderi* (*Bin*) and *S. siliquosum* (*Sil*)

However, the correlation matrix shows weak significance only with salinity (r = 0.5419) and ammonia (r = −0.4603).

Discussion

Majority of samples studied were in the lower length classes (<200 mm) (*S. polycystum* = 86.47 %; *S. binderi* = 87.08 %; *S. siliquosum* = 86.96 %). This is comparable to another study conducted 2.5 km away in Cape Rachado of Port Dickson, where 89 % of *S. binderi* plants were found to be shorter than 200 mm (Wong and Phang 2004). Wong and Phang explained that this is because most of the local *Sargassum* plants have adapted to live within the intertidal zone where waves are strong and desiccation stress is high. Thus, survivors that can resist such physical stress were found to be in smaller length classes. However, the environment of Teluk Kemang allows *Sargassum* to grow up to relatively large sizes (*S. polycystum*, 800–899 mm; *S. binderi*, 500–599 mm; *S. siliquosum*, 900–999 mm). This creates a population of large size inequality, as indicated in the relatively large standard deviations for monthly MTL throughout the year (Fig. 4). In neighbouring countries, large-sized *Sargassum* is not common, such as in the Philippines (*S. polycystum*, <900 mm) (Trono 1997, 1999) and Thailand (*S. polycystum*, <2,000 mm; *S. binderi*, <460 mm) (Noiraksa et al. 2006). Curiel et al. (1998) explained that, in native countries, members of the genus *Sargassum*, such as *S. muticum*, tend to achieve smaller thallus lengths due to strong competition.

It has been reported that a typical life cycle of *Sargassum* includes growth, reproduction and degeneration (Ang 2006). The growth phase is defined by the author as the period of time

Table 1 Summary of RDA results based on log-transformed data of *Sargassum* monthly MTL and environmental parameters

Axes	1	2	3	4	Total variance
Eigenvalues	0.210	0.038	0.023	0.712	1.000
Species–environment correlations	0.491	0.734	0.632	0.000	
Cumulative percentage variance					
Of species data	21.0	24.8	27.1	98.3	
Of species–environment relation	77.7	91.6	100.0	0.0	
Sum of all eigenvalues					1.000
Sum of all canonical eigenvalues					0.271

whereby increment of thallus length occurs. In the present study, two periods of peak growth within a year were seen, as summarised in Table 3. For all three species, timing of the two growth phases was similar, i.e., from December 2009 to February 2010 (*S. binderi*: November 2009 to February 2010) and from April 2010 to July 2010.

The reproductive phase is characterised by the appearance of receptacles, normally towards the end of the growth phase. Within the span of 13 months, three occasions of receptacles appearing were seen for all three *Sargassum* species, indicating that *Sargassum* species in Teluk Kemang undergo a biannual reproductive cycle. In most reefs, an annual cycle is more commonly reported for *Sargassum*, for instance, *S. thunbergii* (Mertens ex Roth) Kuntze in China (Zhang et al. 2009). Wong (1997) reported that within a period of 15 months, *S. baccularia* in Cape Rachado, Port Dickson, produced receptacles at two occasions while *Sargassum swartzii* at three occasions. Some species of *Sargassum* may resort to biannual reproduction as an adaptive strategy to survive in harsh environments (Akira and Masafumi 1999).

For tagged samples of *S. polycystum* and *S. binderi*, appearances of receptacles were strictly within a short time frame of 3–4 months (*S. polycystum*: Sept 2009 to Oct 2009, Jan 2010 to Apr 2010, and Jul 2010 to Sept 2010) (*S. binderi*: Sept 2009 to Oct 2009, Feb 2010 to Apr 2010, and Jun 2010 to Sept 2010). Receptacles of *S. siliquosum* were consistently seen almost every month (except in November 2009 and June 2010). In Cape Rachado of Port Dickson, Wong and Phang (2004) reported *S. binderi* to be reproductively active throughout the whole year and continuously recruiting new plants every month. Continuous reproduction, as opposed to a strict seasonal reproduction is a phenomenon common in certain *Sargassum* species. This can be beneficial for its survival but at the cost of more energy allocation for reproductive structures than vegetative structures. In the absence of receptacles, *S. polycystum* was observed to reproduce vegetatively through the stoloniferous holdfasts (field observation). Due to its tendency to reproduce vegetatively, overall percentage fertility of *S. polycystum* (7.87 %) was found to be lower compared to *S. binderi* (13.36 %) and *S. siliquosum* (14.52 %).

The degenerative phase which is characterised by decrease in MTL includes both senescence and dieback. In this study, three occurrences of degeneration were noted within the span of 13 months (Table 3); from September 2009 to December 2009 (*S. binderi*: September 2009 to November 2009), from February 2010 to May 2010 (*S. siliquosum*: March 2010 to May 2010) and from and July 2010 to September 2010. Samples reached highest degenerative rate in September 2010 (*S. polycystum*, −3.75 mm day^{-1}; *S. binderi*, −3.23 mm day^{-1}; *S. siliquosum*, −5.22 mm day^{-1}).

Most members of the genus *Sargassum* are perennial plants that are able to live through several rounds of growth cycles in its lifetime. It has been reported that during periods of harsh environments, *Sargassum* would dieback and leave a short primary axis attached to its perennial holdfast (Zhang et al. 2009). When conditions are ideal, primary branches arise again from the surviving thallus until the onset of reproduction again. It could take several years before *Sargassum* senesce and die off. Thus, tagging each individual plant by using a nondestructive method would ensure a more accurate representation of a typical *Sargassum* life history.

Table 2 Summary of correlation matrix between *Sargassum* MTL from nondestructive sampling and environmental variables

Species	Water temperature	pH	Salinity	Nitrate	Ammonia	Phosphate	Rainfall	Radiation	Ambient temperature
S. polycystum	−0.0636	0.0917	−0.2230	−0.1416	0.2048	0.2416	−0.0055	0.0702	−0.1567
S. binderi	0.1151	0.2050	−0.0244	−0.2155	−0.0825	−0.2125	−0.0320	0.0124	0.5395*
S. siliquosum	−0.0112	0.4124	0.5419*	0.3457	−0.4603*	−0.1900	−0.2124	-0.3186	-0.1490

*$p < 0.05$

Table 3 Periods of *Sargassum* growth and degeneration phases in Teluk Kemang from September 2009 to September 2010

Life cycle stages	Nondestructive sampling		
	S. polycystum	*S. binderi*	*S. siliquosum*
Reproduction 1	Sept 09–Oct 09	Sept 09–Oct 09	Sept 09–Oct 09
Degeneration 1	Sept 09–Dec 09	Sept 09–Nov 09	Sept 09–Dec 09
Growth 1	Dec 09–Feb 10	Nov 09–Feb 10	Dec 09–Feb 10
Reproduction 2	Jan 10–Apr 10	Feb 10–Apr 10	Dec 09–May 10
Degeneration 2	Feb 10–Apr 10	Feb 10–Apr 10	Feb 09–May 10
Growth 2	Apr 10–Jul 10	Apr 10–Jul 10	Apr 10–Jul 10
Reproduction 3	Jul 10–Sept 10	Jul 10–Sept 10	Jul 10–Sept 10
Degeneration 3	Jul 10–Sept 10	Jul 10–Sept 10	Jul 10–Sept 10

Figure 5 revealed two occasions whereby tagged samples experienced peak growth rate, which was in February 2010 (January 2010 for *S. polycystum*) and June 2010 (July 2010 for *S. siliquosum*). This is in agreement with a study in Cape Rachado of Port Dickson, located only 2.5 km away, whereby growth rate of *S. baccularia* and *S. binderi* also attained two peaks in June 1995 and February 1996 (Wong 1997). Similarly, degenerative rate of the current study was highest in April 2010 and September 2010. Wong found that high degenerative rate of *S. baccularia* occurred between February to March 1995, in April 1995, early June 1995 and between June to July 1995. For *S. binderi*, Wong (1997) found that high degenerative rate occurred between March and April 1995; between June and July 1995; and between September and October 1995. This proves that seasonal growths of *Sargassum* samples in Teluk Kemang are similar to those from Cape Rachado in terms of growth rate.

According to Fig. 5, the growth rate of *Sargassum* decreased from June 2010 to July 2010 (except for *S. siliquosum*). In the field, abundant *Sargassum* seaweeds were found washed onto shore in late July 2010 (field observation). Most of these were observed to be whole plants with attached holdfasts.

RDA results showed that ambient temperature, salinity and ammonia are the most important environmental factors affecting *Sargassum* growth. In the duration of this study, ambient air temperature of Teluk Kemang, obtained from the Malaysian Meteorological Department ranged from 26 to 28 °C. Due to its spatial distribution, *S. siliquosum* of Teluk Kemang is mainly found in the lower intertidal zone that allows it to be submerged in the water most of the time, even during low tides. This sheltered *S. siliquosum* from harsh desiccation stress inflicted by the scorching tropical sun. This was evident in the current study when high ambient air temperature was not detrimental to *S. siliquosum* growth but instead encouraged it. In fact, a study in Taiwan found that *S. siliquosum* experienced maximum growth rate at higher temperatures (30 °C) (Hwang et al. 2004).

Changes in monthly seawater salinity are dependent on seasonal water circulation and retention on the reefs. During daily low tides, seawater is trapped on the depressions and crevices of Teluk Kemang reefs due to uneven surface of the reefs. The trapped water evaporates under scorching sun, causing water temperature and salinity to increase during reef emersion, as also mentioned by Lobban and Harrison (1994). Inversely, salinity decreases as seawater is diluted during daily high tides, especially on rainy seasons. In the present study, the salinity of seawater collected from the reefs of Teluk Kemang ranged from 20 to 30 ‰.

Throughout the course of the study, effluent waste was constantly released into the sea by the resort fronting the reefs. Thus, high ammonia levels from effluent waste discouraged growth of *Sargassum* on the reefs. However, this is not always the case as blooms of *Sargassum* have been reported elsewhere in waters with high concentrations of dissolved nutrients (Hwang et al. 2004; Chung et al. 2007). For instance, high nutrient concentrations in water of southern Taiwan encouraged growth of *S. siliquosum.* In Teluk Kemang, other factors such as desiccation stress could have acted as the limiting factor for *Sargassum* growth.

Despite its natural abundance along Malaysian coasts, seaweed cultivation is solely carried out in Sabah, mainly off the coast of Semporna, Kunak, Kudat and Lahad Datu (Ahemad et al. 2006). Currently, only 11 local companies of producers and suppliers of seaweed products were listed in the official directory of the Department of Fisheries Malaysia. It is mostly focusing on red seaweeds for food and carrageenan production, with none on *Sargassum* species (Department of Fisheries Malaysia 2011). Malaysian government encourages the cultivation of seaweeds and high-end new products for seaweeds. At the moment, most products are concentrated on the red seaweeds. However, the country has abundant brown seaweeds. Utilisation of brown seaweeds will be timely and expanded in the future. With the expansion of the industry, the natural population would not be able to sustain the volume needed in the industry. Thus, study of the growth of species will give an idea as to the best time and sustainable way to harvest the natural population and, at the same time, the data will indicate when will be the good time for cultivation. In addition, this study also will give an idea if all species have the same pattern of growth, reproduction and dieback. Thus, the baseline data collected from this study will help in determining the optimum time for a natural harvest, for example, harvesting should not be done during the peak period of reproduction nor should the cultivation of these three species be done during the period of dieback.

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