CHAPTER 4

RESULTS

CHAPTER 4

RESULTS

4.1 Description of the Species

4.1.1 *Sargassum baccularia* (Mertens) C. Agardh

(Figure 7, Plates 5-8)

C. A. Agardh 1824, p. 304; J. G. Agardh 1848, p. 307; 1889, p. 119, tab. 31, fig. 4; Reinbold 1913, p. 171; Grunow 1916, p. 12; Setchell 1936, p. 12, pl. 2, figs. 4-7, pl. 3, figs. 1-5; Pham-Hoang 1967, p. 314; Ang 1982, p.35, pl. X; Ang and Trono 1987, p. 389, fig. 1A; Tseng and Lu 1992, p. 17, figs. 1, 17; Trono 1992, p. 46, fig. 93.

Synonym : *Fucus baccularia* Mertens, Mém. Mus. d'Hist. Nat. 5, p. 6, 1819.

Holdfast scutate. Plants are dark-brown when dried. Stem short, terete, verrucose, about 10 - 15 mm long. Fertile plants reach 25 cm (male) and 43 cm (female) in height. Nonfertile plants reach 34 cm. Out of forty plants examined, only eight plants are fertile (four male and four female plants). Primary branches usually arise about 10 mm from the holdfast, arrange alternately and about 1 mm apart. Secondary branches radially arranged on primary branches. Both primary and secondary branches are terete and verrucose with spines (about 1 to 2 mm long), more obvious in young and nonfertile plants (Plate 5).

Leaves are ovate-lanceolate, lanceolate to elliptical, up to 55 mm long and 20 mm wide. Margin entire or dentate, obtuse at the apices, base slightly attenuate with a petiole of about 1 mm long. Midrib distinct and vanishing at the upper parts; cryptostomata numerous, distinct, slightly elevated and scattered randomly at both sides of midrib (Figure 7b).

Vesicles spherical to subspherical with elevated cryptostomata, usually solitary and small, 1 to 2 mm in diameter (sometimes up to 4 mm in diameter), few in young plants, with stalks terete less than half the length of the vesicle.

Plants dioecious. Male receptacles cylindrical with smooth to warty outlines (Figure 7a, Plate 6 & 7); 3 to 4 mm long, 0.5 to 1 mm in diameter. Simple or two racemosely arranged, intermixed with vesicles on the axils of the branches. Female receptacles compressed and dentate at the tips, up to 5 mm (Figure 7b and Plate 8). The female receptacles are shorter than the male receptacles.

Remarks : From the sample collections, it was noted that few plants had reproductive structures (receptacles). A few of the materials examined show rhizoids arising from the primary branches.

Habitat : On dead corals and sand between corals..

Geographical distribution : Singapore (type locality) (Tseng & Lu 1992), Indonesia, Philippines, Taiwan, Vietnam (Trono 1992; Tseng & Lu 1992) and west coast of Malaysia (Phang & Wee 1991; Phang 1995).

4.1.2 *Sargassum swartzii* (Turner) C. Agardh

(Figure 8, Plates 9-12)

C. A. Agardh 1820, p.11; J. Agardh 1848, p.328; 1889, p.85; Grunow 1916, p.381; Setchell 1931, p.250; 1936, p. 3, pl.1; Yoshida 1988, p.19, fig. 18; Tseng and Lu 1995, p. 79, figs. 2, 10.

Basionym : *Fucus swartzii* Turner (Turner 1819, p. 110, pl. 248).

Application of this name : Yamada 1942, p.371, fig. 1.

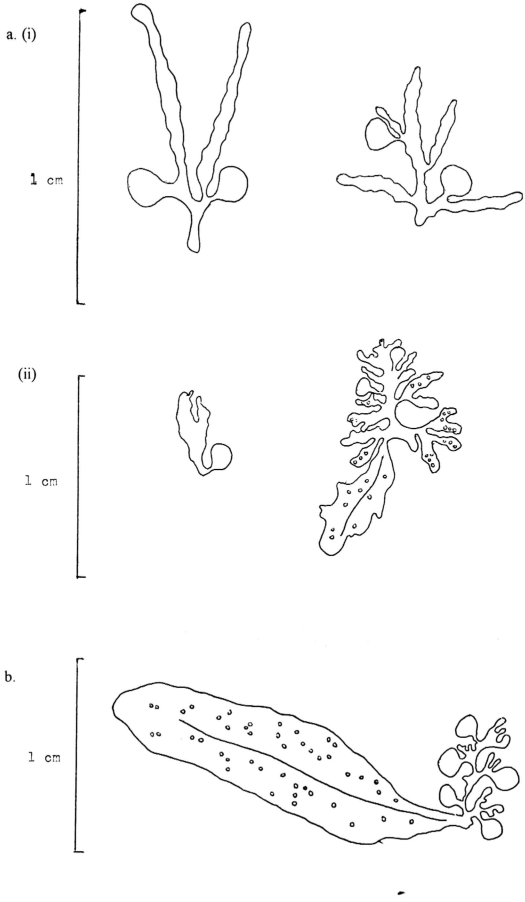


Figure 7. *Sargassum baccularia* (Mertens) C. Agardh.
a. Vesicles and receptacles (i) male (ii) female. b. Leaves.

Plate 5. Whole plant of *S. baccularia* dried specimen.

Plate 6. *S. baccularia* : Male receptacular branch.

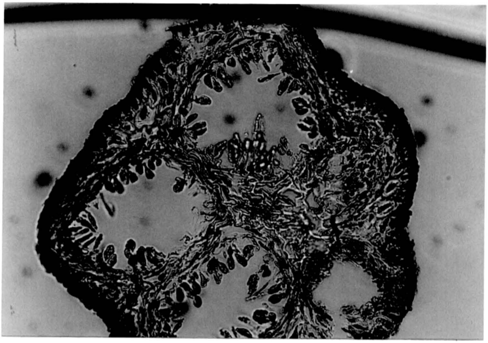


Plate 7. *S. baccularia* : Cross-section of male receptacle.

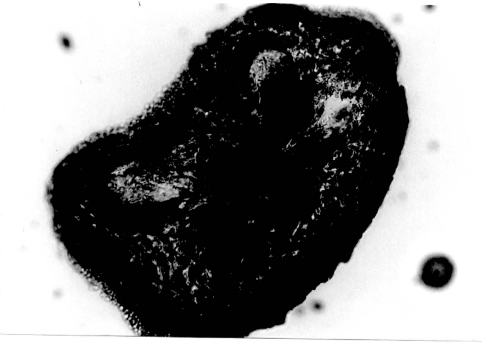


Plate 8. *S. baccularia* : Cross-section of female receptacle.

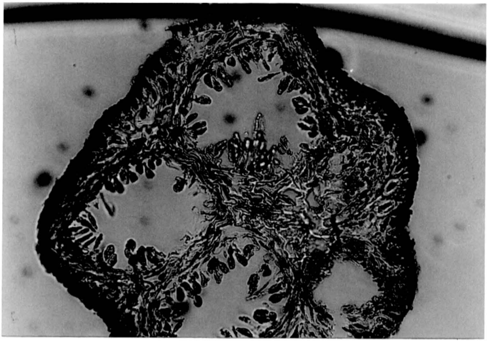


Plate 7. *S. baccularia* : Cross-section of male receptacle.

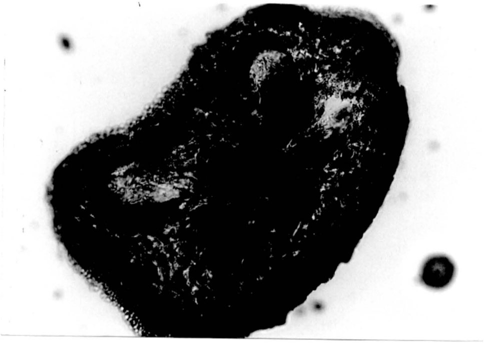


Plate 8. *S. baccularia* : Cross-section of female receptacle.

Plants are yellowish-brown to dark brown when dried. Holdfast disc-shaped. Stem short and terete, 5 mm long, bearing apically and radially 3 to 5 primary branches. Plants reach 37 cm in height. Primary branches flattened and compressed, broader at the base, without spines (Plate 9). Secondary branches alternately distichously branched from both sides of the primary branches, short and flattened at intervals of 2 to 4 cm.

Leaves are thick, lanceolate to linear-lanceolate, up to 8 cm long, 2 cm wide, margin with small teeth or acute teeth, percurrent midrib with crytostomata forming two rows on both sides (Figure 8b). Leaves from primary branches are usually broader than leaves from secondary branches.

Vesicles are variable (Plate 10), up to 32 mm long, 3 mm wide (sometimes reach 7 mm), with round apex or with a sharp point, with or without wing, varying from large to small minute near apex of branch, subellipsoidal to ellipsoidal, with long flat and leafy pedicels (up to 25 mm), with the presence of crytostomata.

Plants androgynous (Plate 11 & 12). Receptacles compressed, twisted, furcate, up to 7 mm long, with short and closely packed acute spines, cymosely arranged (Figure 8a, Plate 11).

Remarks : From the collections, it was observed that vesicles are seldom found on the fertile plants. Fertile plants are found throughout the year at the sampling site.

Habitats : On dead corals and sand between corals.

Geographical distribution : Indian oceans (type locality), Vietnam and tropical Australia (Yoshida 1988; Noro *et al.* 1994), China, Hong Kong, widely distributed in the Indo-West Pacific region (Tseng & Lu 1995).

4.2 Preliminary Study

Different analyses were used to determine the most suitable quadrat size for biomass sampling. Results using the Wiegert's nested quadrats are shown in Figure 9, which indicates that the 1.0 m quadrat frame is the most suitable quadrat size to be used in the study for both *Sargassum* species.

Table 7 shows the number of selected quadrats and its p value for *S. baccularia* ($p \leq 0.01$) and *S. swartzii* ($p \leq 0.1$) derived from the formula [$n = (t.s)^2/D.x$].

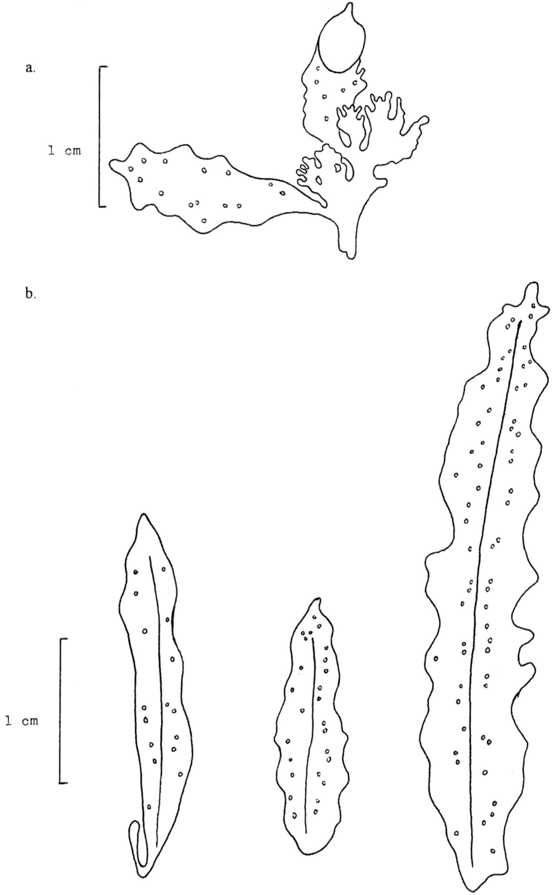


Figure 8. *S. swartzii* (Turner) C. Agardh.
a. Vesicles and receptacles. b. Leaves.

Plate 9. Whole plant of *S. swartzii* dried specimen.

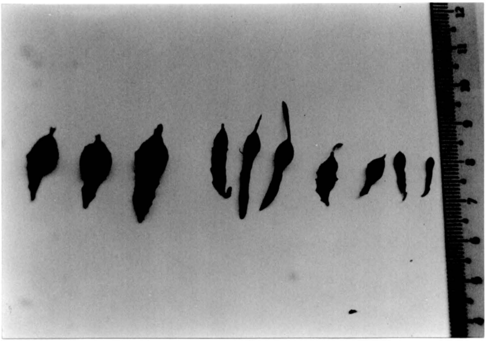


Plate 10. Morphological variations of vesicles in *S. swartzii.*

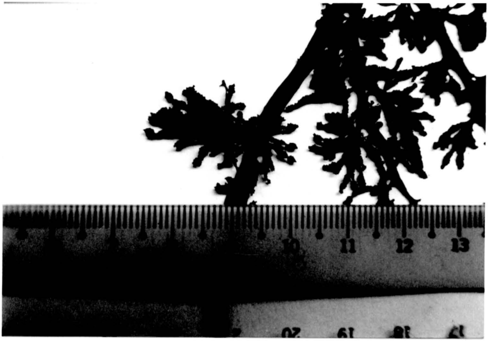


Plate 11. *S. swartzii* : Receptacular branch.

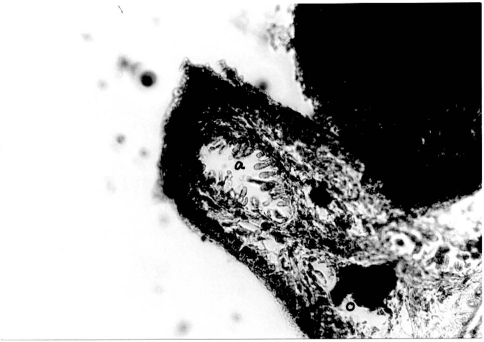


Plate 12. *S. swartzii* : Cross-section of androgynous receptacle showing antheridia (a) and oogonia (o).

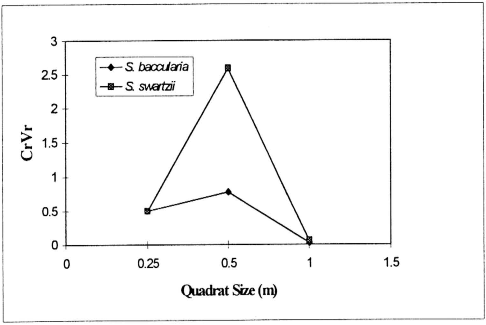


Figure 9. Plot of V_rC_r against quadrat size for biomass (ash-free dry weight) collected using Wiegert's nested quadrat.

Table 7. Number of quadrats for biomass (ash-free dry weight) needed to be taken in order to get accurate samples from the study area.

Quadrat Size (m)	*S. baccularia* ($p \leq 0.01$)	*S. swartzii* ($p \leq 0.1$)
0.25	64	33
0.5	35	54
1.0	106	97

From these results, the most appropriate quadrat size is 0.5 m for *S. baccularia* population and 0.25 m for *S. swartzii* population, as the number of samples needed to be taken were reasonable without destroying much of the plants in an available time.

ANOVA ($p \leq 0.5$) was used to determine any significant differences in biomass between the different size of quadrats (0.25 m, 0.5 m and 1.0 m) used for both species. The analysis denotes a significant difference between the different quadrats size for *S. baccularia* plants, but not for *S. swartzii* plants. Multiple range test (LSD) tested at 95% confidence level shows statistically significant difference between 0.25 m quadrat with 0.5 m and 1.0 m quadrat for *S. baccularia* plants.

Therefore, the 0.25 m quadrat frame was chosen for both *Sargassum* species for three reasons. Firstly, to standardize the methodology for both species. This would minimize errors in calculations when any comparison is involved. Secondly, to minimize sampling damage; and, finally to provide adequate replication.

4.3 15-Month Studies

The means and standard deviations for all the data in this section are given in Appendix 5 and 6.

4.3.1 *Sargassum baccularia*

4.3.1.1 Seasonal Variation in Mean Thallus Length

Figure 10 (Appendix 5) shows the seasonal variation in mean thallus length with standard deviation bar for *S. baccularia*. Four trends have been observed over the monitoring period (from January 1995 to March 1996). Thallus length of *S. baccularia* plants declined from a high value of 242.96±108.16 mm in January 1995 to 88.18±45.15 mm in April 1995. The length rose again to a value of 98.23±66.00 mm in June 1995. Then it dropped gradually to a minimum length of 26.75±16.85 mm in December 1995. Thereafter the thallus length increased again to 51.64±41.40 mm in March 1996.

4.3.1.2 Seasonal Variation in Growth Rate and Degenerative Rate

Figures 11a and 11b (Appendix 5) show the seasonal variation in growth rate and degenerative rate with standard deviation bar for *S. baccularia*. Highest growth rate was recorded in June 1995 (3.01±3.36 mm day^{-1}), which slowed down thereafter until a zero growth rate was recorded between November to December 1995. The plants grew slowly again and reached another high growth rate in February 1996 (1.48±1.40 mm day^{-1}). High degenerative rate was observed between February to March 1995 (-3.21±2.85 mm day^{-1}), in April 1995 (-3.31±1.66 mm day^{-1}) and early June 1995 (-3.13±3.84 mm day^{-1}), with the highest degenerative rate occurred between June to July 1995 (-4.81±4.88 mm day^{-1}). Then, it gradually approaching zero from August onwards.

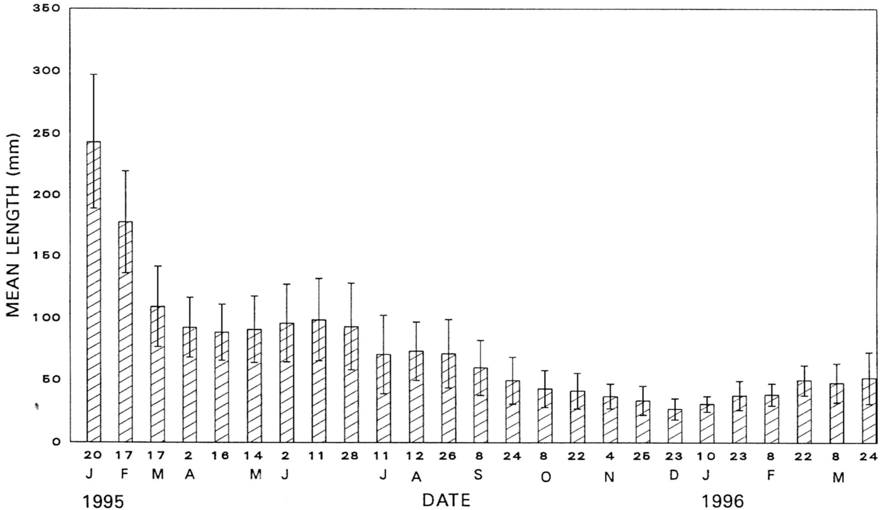


Figure 10. *S. baccularia* : Mean thallus length with standard deviation bars.

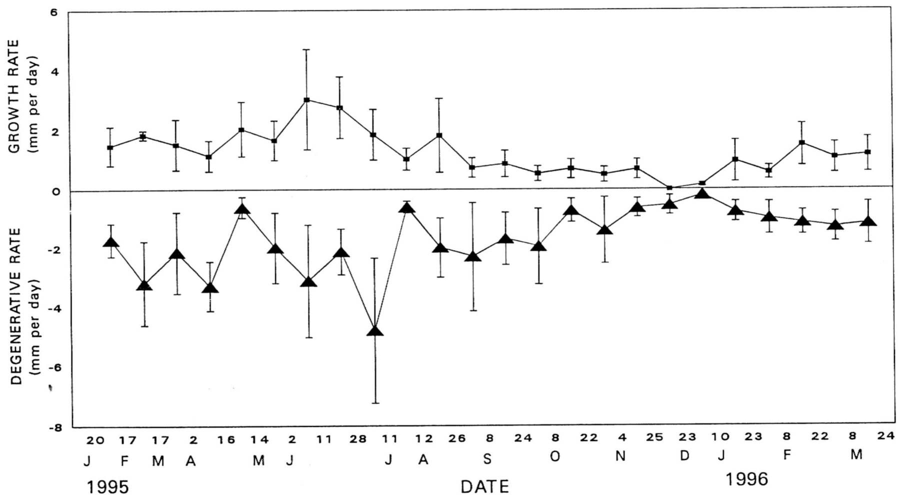


Figure 11. *S. baccularia* : Mean (a)growth rate (b)degenerative rate with standard deviation bars.

4.3.1.3 Correlation Between Mean Thallus Length, Growth Rate and Degenerative Rate

Simple correlation analysis was used to find the relationship between the mean thallus length, growth rate and degenerative rate of *S. baccularia* plants. Growth rate of the plants showed a stronger correlation to mean thallus length than to degenerative rate. Growth rate of the plants were positively correlated to the increase of the mean thallus length ($r = 0.5088$, $p \leq 0.01$). Whereas, the degenerative rate of the plants gave a negative correlation with the decrease of the mean thallus length ($r = -0.4770$, $p \leq 0.01$). Significant difference (ANOVA, $p \leq 0.05$) was found between mean thallus length from different months. Multiple range test (LSD) tested at 95% confidence level gave a significant difference in thallus length between February 1995 and March 1995.

4.3.1.4 Seasonal Variation in Reproductive State

Figure 12 (Appendix 5) gives the comparison between the percentage fertility (plants bearing receptacles) and mean thallus length of *S. baccularia* population.

S. baccularia plants produced receptacles twice over the monitoring period, between January-February 1995 and late June-August 1995

(Fig. 11). The percentage fertility was very low from a range of 1.35% - 15.62% (Appendix 5). The percentage of female plants were extremely low with only one plant found in February 1995.

The plants became fertile during the time when they had the longest thallus length (Figure 12). Mean thallus length of the plants had a strong correlation with the number of plants bearing receptacles ($r = 0.6130$, $p \leq 0.001$), but had a weak correlation with the growth rate ($r = 0.1857$, $p \leq 0.05$) and degenerative rate ($r = -0.3416$, $p \leq 0.05$). ANOVA ($p \leq 0.05$) showed a significant difference between the number of plants bearing receptacles at different months.

4.3.1.5 Seasonal Variation in Length Classes

Percentage of individuals in various length classes of *S. baccularia* is shown in Figure 13 (Appendix 7a).

In the *S. baccularia* population, the average length was 68.16±59.30 mm with 96% of the population being shorter than 199 mm (Appendix 7a) from a wide range of 5 - 445 mm. Out of this, 50% of the population was shorter than 49 mm (Figure 13).

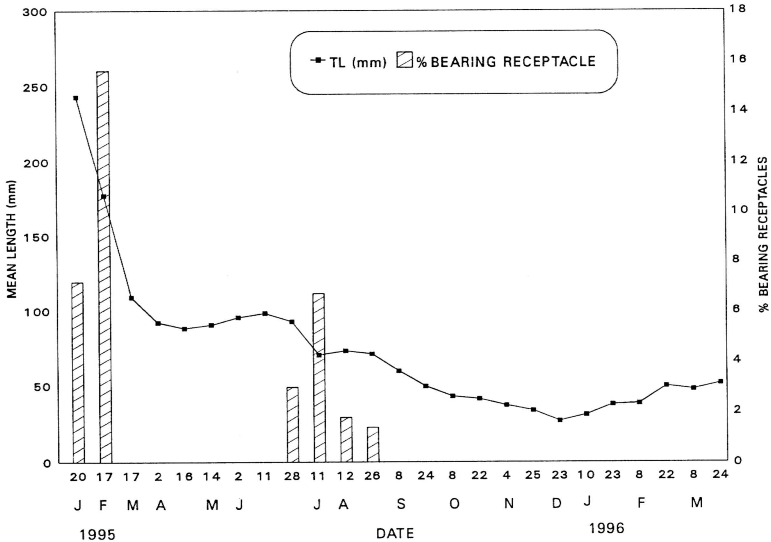


Figure 12. *S. baccularia* : Comparison between mean thallus length and percentage fertility.

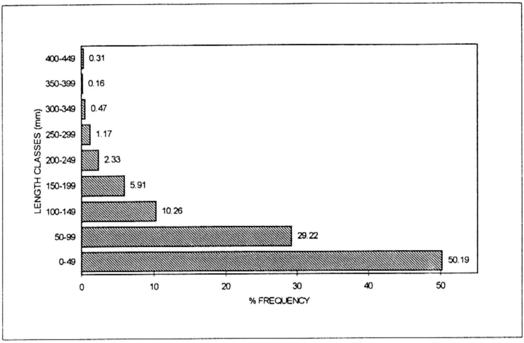


Figure 13. Length classes of *S. baccularia.*

4.3.2 *Sargassum. swartzii*

4.3.2.1 Seasonal Variation in Mean Thallus Length

Figure 14 (Appendix 6) shows the seasonal variation in mean thallus length with standard deviation for *S. swartzii.* Similar to *S. baccularia,* four trends have been observed over the monitoring period (January 1995 to March 1996). The plants declined abruptly in size from a high value of 236.03±91.91 mm in January 1995 to 58.12±47.06 mm in early April 1995, rose again to a value of 95.35±56.97 mm in mid-June 1995, declined after June 1995 to a minimum value of 16.40±5.41 mm in late November

1995. Then the plants reached another high value of 175±190.92 mm in March 1996.

4.3.2.2 Seasonal Variation in Growth Rate and Degenerative Rate

Figures 15a and 15b (Appendix 6) show the seasonal variation in growth rate and degenerative rate with standard deviation for *S. swartzii*. The plants grew fast in early June 1995 (3.31±3.12 mm day^{-1}) and slowed down after June 1995 to a minimum growth rate of 0.12±0.10 mm day^{-1} in November 1995. The plants reached the fastest growth between February and March 1996 with a value of 3.52±3.44 mm day^{-1}. The highest degenerative rate occurred between March-April 1995 (-4.42±4.72 mm day^{-1}), June-July 1995 (-4.41±2.88 mm day^{-1}) and September-October (-4.88±4.98 mm day^{-1}).

4.3.2.3 Correlation Between Mean Thallus Length, Growth Rate and Degenerative Rate

Correlation analysis showed that both the growth rate ($r = 0.0850$, $p \leq 0.05$) and degenerative rate ($r = -0.3440$, $p \leq 0.05$) were poorly correlated with the mean thallus length of the plants. ANOVA ($p \leq 0.05$)

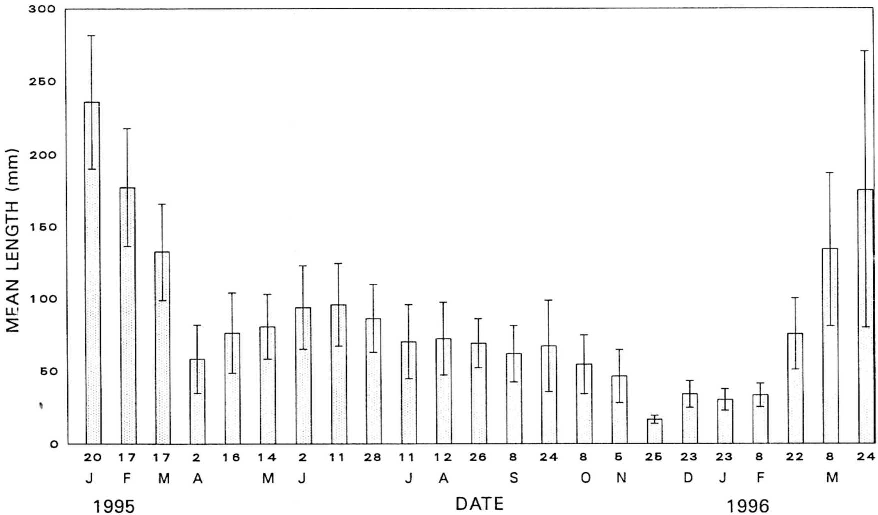


Figure 14. *S. swartzii* : Mean thallus length with standard deviation bars.

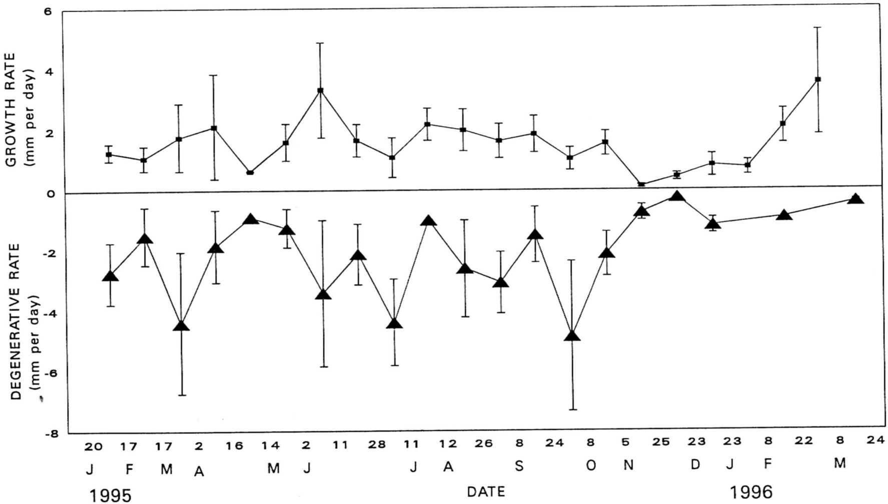


Figure 15. *S. swartzii* : Mean (a)growth rate (b)degenerative rate with standard deviation bars.

showed that there was a significant difference between the different months for the mean thallus length of the plants. Multiple range test (LSD) tested at 95% confidence level showed that there was a significant difference in the mean thallus length between January-February 1995, March-April 1995 and February-March 1996.

4.3.2.4 Seasonal Variation in Reproductive State

Figure 16 (Appendix 6) gives the comparison between the percentage fertility (plants bearing receptacles) and mean thallus length of *S. swartzii* population.

S. *swartzii* plants were fertile three times throughout the monitoring period, ranging from 0.03% in early September 1995 to 60% in early March 1996 (Appendix 6), and they were all female plants. The plants did not produce receptacles in April 1995 and late November 1995 to February 1996, which coincided with the shortest thallus length of the plants (Figure 15).

There was a strong correlation between mean thallus length and the number of plants bearing receptacles ($r = 0.8504$, $p \leq 0.001$). The number of plants bearing receptacles was poorly correlated to the growth rate

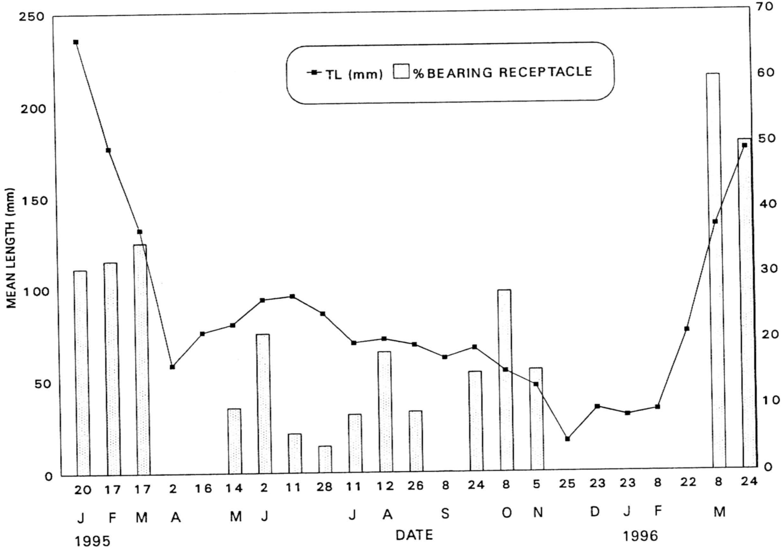


Figure 16. *S. swartzii* : Comparison between mean thallus length and percentage fertility.

(r = 0.0137, p $\leq$ 0.05) and degenerative rate (r = -0.3316, p $\leq$ 0.05). ANOVA (p $\leq$ 0.05) showed no significant difference between the number of plants bearing receptacles at different months.

4.3.2.5 Seasonal Variation in Length Classes

Percentage of individuals in various length classes of *S. swartzii* is shown in Figure 17 (Appendix 7b).

In *S. swartzii* population, the average length was 93.17±73.89 mm with 90% of the population shorter than 199 mm (Appendix 7b) from a wide range of 3 - 455 mm. 66% of the population was shorter than 99 mm (Figure 17).

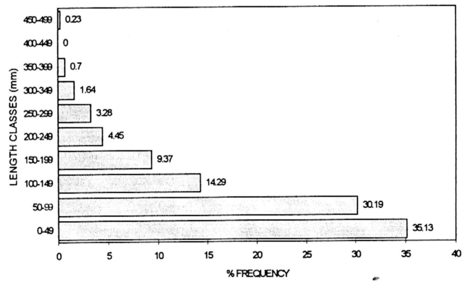


Figure 17. Length classes of *S. swartzii*.

4.4 Quarterly Monitoring of the *Sargassum* species

The means and standard deviations for all the data in this section are given in Appendix 8 - 13. Figures 18 to 20 show the biomass of *S. baccularia*. Figures 27 to 29 show the biomass of *S. swartzii*.

4.4.1 *Sargassum baccularia*

4.4.1.1 Mean Quarterly Biomass

Figure 18 shows a similar trend obtained by the wet weight (WW), dry weight(DW) and ash-free dry weight (AFDW) of *S. baccularia* population over the monitoring period (Appendix 8). The biomass of the population showed an unimodal pattern and two peaks over a period of 15 months. Peak biomass was obtained in January 1995 (520.23±724.37 g WW m^{-2} , 47.88±65.47 g DW m^{-2} and 13.35±16.69 g AFDW m^{-2}) and July 1995 (501.98±341.05 g WW m^{-2} , 64.92±40.99 g DW m^{-2} and 14.00±9.65 g AFDW m^{-2}). The lowest biomass occurred in January 1996 at 76.14±37.97 g WW m^{-2} , 9.97±4.62 g DW m^{-2} and 1.97±1.00 g AFDW m^{-2}.

One-way ANOVA test ($p \leq 0.05$) of the raw biomass data confirmed that a highly significant difference exists among the sampling means.

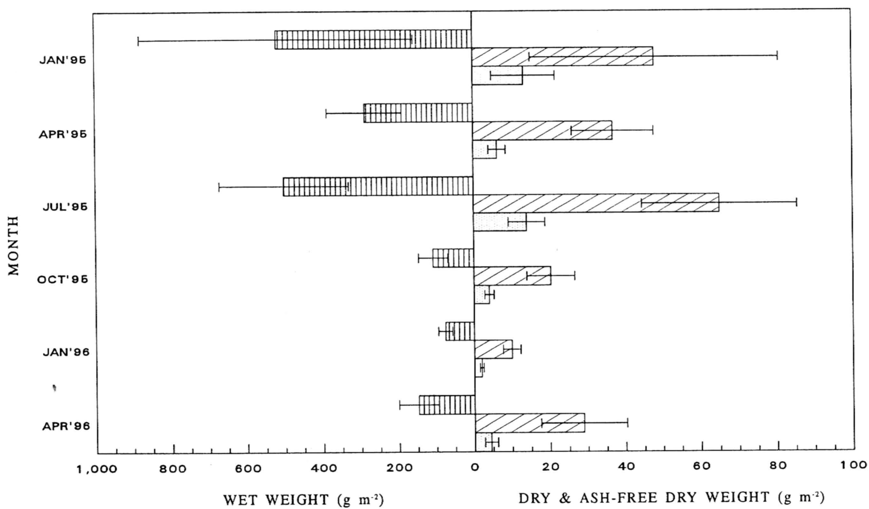


Figure 18. Seasonal variation in biomass of *S. baccularia* with standard deviation bars.

4.4.1.2 Variation in Biomass Between Line Transects

Figure 19 shows the biomass of *S. baccularia* population between line transects for every destructive sampling from April 1995 to April 1996 (Appendix 9). Multiple range test (95% LSD) was used to study any significant difference of the biomass data between the line transects. The results are given in Table 8.

Table 8. Results of LSD Multiple range test (95% confidence level) to show significant differences for biomass between *line transects* of *S. baccularia* population from April 1995 to April 1996. NS = no significant difference between line transects.

Destructive sampling	Wet weight	Dry weight	Ash-free dry weight
April 1995	*2&3; 3&6	2&3; 3&6	NS
July 1995	1&3,6; 2&6; 4&6	1&3,5,6; 2&6; 4&6	1&3,4,5,6; 2&6
October 1995	3&4	NS	NS
January 1996	1&3,5; 3&4; 4&5	NS	NS
April 1996	NS	1&4; 2&4; 3&4; 4&5,6	NS

4.4.1.3 Variation in Biomass Between Station Levels (Quadrats)

The biomass increased from the landward to the seaward. Only significant difference was shown in April 1995 and July 1995 for ash-free dry weight (Table 9). Figure 20 (Appendix 10) shows the difference of biomass between the station levels (quadrats) from April 1995 to April 1996.

Table 9. Results of LSD Multiple range test (95% confidence level) to show significant differences for biomass between *quadrats* of *S. baccularia* population from April 1995 to April 1996. NS = no significant difference between quadrats.

Destructive sampling	Wet weight	Dry weight	Ash-free dry weight
April 1995	*1&8; 2&3,8; 3&9; 8&9	1&2,7,9	1&8; 2&8; 4&8; 5&8; 6&8; 7&8; 8&9; 8&10
July 1995	NS	1&7,9; 4&7,9	1&7,9; 4&9
October 1995	1&7; 7&10	1&7	NS
January 1996	NS	1&3,6,7,9,10	NS
April 1996	9&10	NS	NS

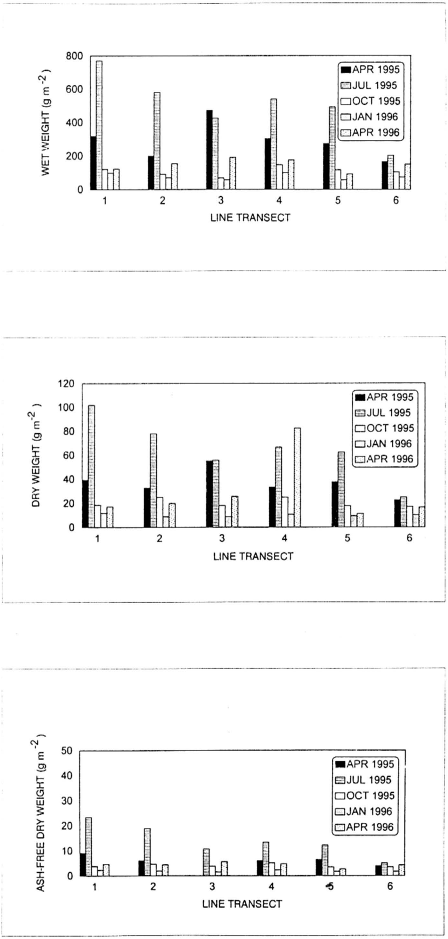


Figure 19. Biomass of *S. baccularia* for every destructive sampling from April 1995 to April 1996.

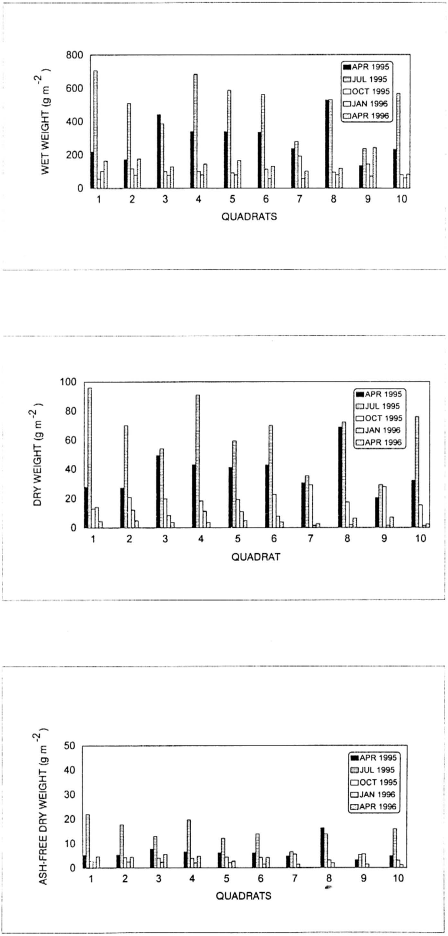


Figure 20. Biomass of *S. baccularia* between station levels (quadrats) from April 1995 to April 1996.

4.4.1.4 Comparison Between Biomass and Mean Thallus Length

Figure 21 (Appendix 8) shows the comparison between the mean thallus length and biomass of *S. baccularia.*

Mean thallus length of the plants was strongly correlated with the wet weight ($r = 0.9826$, $p \leq 0.05$), dry weight ($r = 0.8783$, $p \leq 0.05$) and ash-free dry weight ($r = 0.9777$, $p \leq 0.05$); the increase and decrease in the thallus length followed the trend of increase and decrease in biomass (Figure 21). Therefore, the peak period of the thallus length coincided with the peak period of biomass.

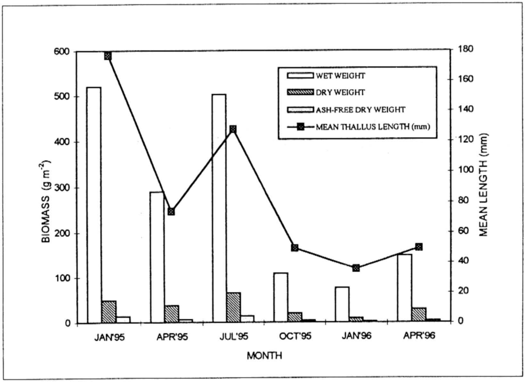


Figure 21. Comparison between the mean thallus length (mm) and biomass ($g\ m^{-2}$) of *S. baccularia.*

The mean thallus length between line transects (Figure 22) showed a similar trend to the biomass between line transects (Figure 19).

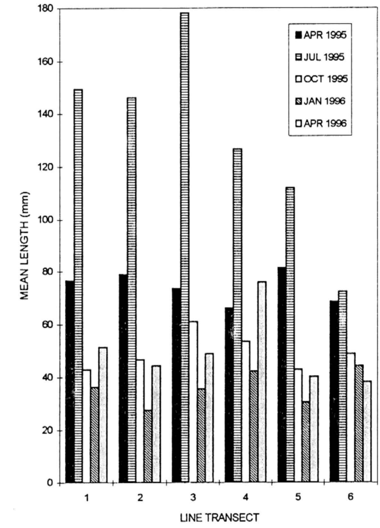


Figure 22. Mean length (mm) of *S. baccularia* for every destructive sampling from April 1995 to April 1996.

4.4.1.5 Seasonal Variation in Length Classes

The seasonal change in the structure of individuals in various length classes are depicted in Figure 23 and Figure 24 (Appendix 15).

In the *S. baccularia* population, the average length was 65.99±60.32 mm with 96% of the population shorter than 199 mm (Figure 22, Appendix 15a). Out of this, 54% of the population was shorter than 49 mm.

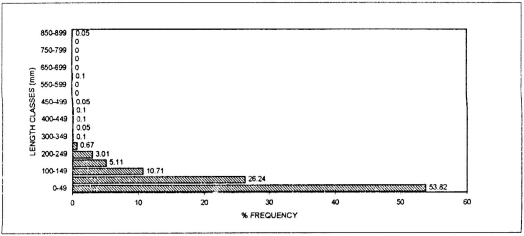


Figure 23. Length classes of *S. baccularia.*

The distribution of the population in various length classes was different for every sampling period from January 1995 to April 1996 (Figure 24, Appendix 16a). In *S. baccularia* population, half of the population was in the 50 - 99 mm length classes in January 1995 (54%) and April (50%). In July 1995, 24% of the population was in the length classes of 100 - 149 mm. More than half of the population was in the length classes of 0 - 49 mm in October 1995 (66%), January 1996 (79%) and April 1996 (67%).

4.4.1.6 Comparison Between Percentage Fertility with Biomass and Mean Thallus Length

Figure 25 (Appendix 8) gives the comparison between percentage fertility and biomass. *S. baccularia* plants recorded zero fertility in January 1995, April 1995 and January 1996. The plants recorded an extremely low percentage fertility in July 1995 (0.54%) and April 1996 (0.44%), as shown in Figures 25 and 26. The population showed a positive correlation with wet weight ($r = 0.6690$, $p \leq 0.05$), dry weight ($r = 0.7505$, $p \leq 0.05$) and ash-free dry weight ($r = 0.7302$, $p \leq 0.05$).

A high percentage fertility was obtained when the plants were having long thallus length (Figure 26), except in the month of January 1995. Correlation test showed a positive correlation ($r=0.5952$, $p \leq 0.05$). Thus, this is the reason why the correlation coefficient is not highly significant.

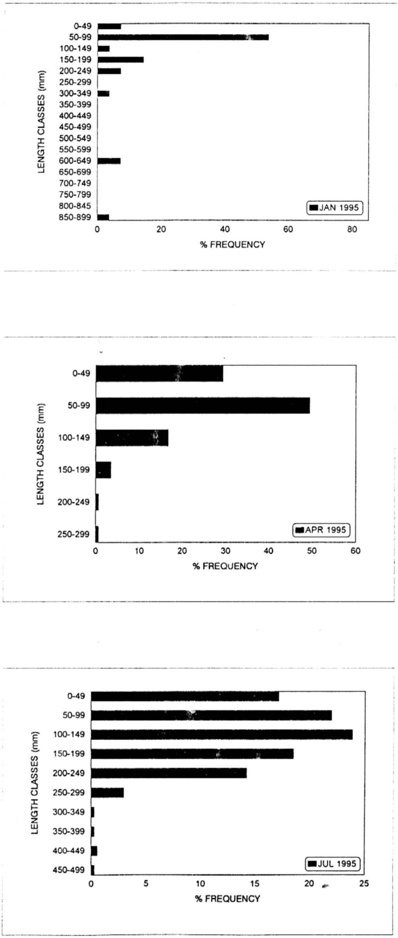


Figure 24. Percentage frequency of *S. baccularia* in various length classes for every destructive sampling.

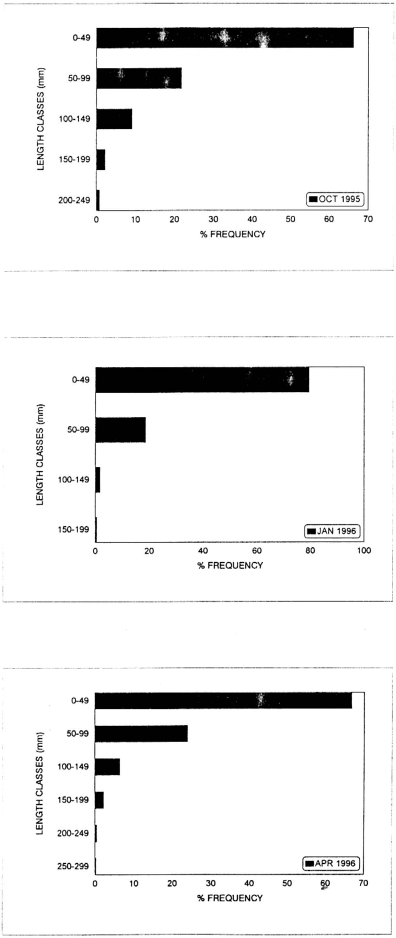


Figure 24. Percentage frequency of *S. baccularia* in various length classes for every destructive sampling (continued).

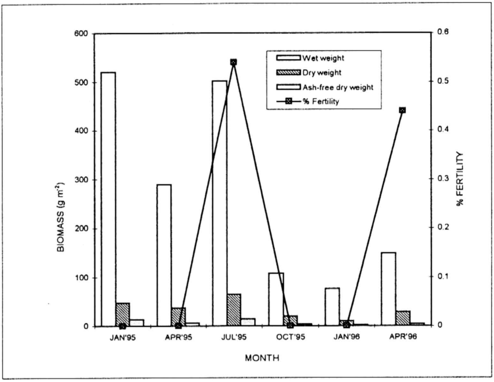


Figure 25. Comparison between percentage fertility and biomass for *S. baccularia.*

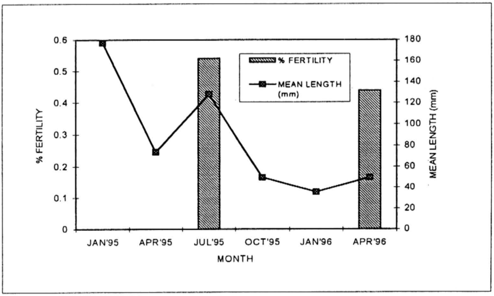


Figure 26. Comparison between percentage fertility and mean thallus length (mm) for *S. baccularia.*

4.4.2 *Sargassum. swartzii*

4.4.2.1 Mean Quarterly Biomass

Biomass of *S. swartzii* population showed an unimodal pattern (Figure 27 and Appendix 11). The population peaked twice over a period of 15 months. The highest value obtained in April 1996 (656.13±735.27 g WW m^{-2}, 80.81±76.02 g DW m^{-2} and 15.25±16.72 g AFDW m^{-2}). July 1995 recorded another high value (429.28±385.64 g WW m^{-2}, 54.30±50.25 g DW m^{-2} and 11.20±11.43 g AFDW m^{-2}). Biomass was the lowest in January 1996 (68.21±33.08 g WW m^{-2}, 8.36±4.07 g DW m^{-2} and 1.68±0.89 g AFDW m^{-2}).

One way ANOVA test ($p \leq 0.05$) of the raw biomass data denoted a significant difference existed among the biomass at different months.

4.4.2.2 Variation in Biomass Between Line Transects

Figure 28 shows the biomass of *S. swartzii* population between line transects for every destructive sampling from April 1995 to April 1996 (Appendix 12). Multiple range test (95% LSD) was used to establish any significant difference of the biomass data between the line transects. The results are given in Table 10.

Table 10. Results of LSD Multiple range test (95% confidence level) to show significant differences for biomass between *line transects* of *S. swartzii* population from April 1995 to April 1996. NS = no significant difference between line transects.

Destructive sampling	Wet weight	Dry weight	Ash-free dry weight
April 1995	NS	NS	NS
July 1995	*2&3,5	2&3,4,5	2&3,4,5
October 1995	NS	NS	NS
January 1996	2&6; 3&6; 4&6; 5&6	4&6; 5&6	4&6
April 1996	NS	1&5; 2&5; 3&5	NS

4.4.2.3 Variation in Biomass Between Station Levels (Quadrats)

S. swartzii population was frequently found growing at around 50 m from the shore towards the sea. The population grew abundantly especially in the 90 m or more towards the sea. Generally, biomass of *S. swartzii* increased from landward to seaward. Significant difference was found in all the destructive sampling between station levels except in January 1996 (Table 11). Figure 29 (Appendix 13) shows the difference of biomass between the station levels (quadrats) from April 1995 to April 1996.

Table 11. Results of LSD Multiple range test (95% confidence level) to show significant differences for biomass between *quadrats* of *S. swartzii* population from April 1995 to April 1996. NS = no significant difference between quadrats.

Destructive sampling	Wet weight	Dry weight	Ash-free dry weight
April 1995	*1&9,10; 2&4,5; 3&10; 4&9,10; 5&9,10; 6&9,10; 7&9,10; 8&9,10	4&9,10; 5-9,10; 6&9,10; 7&9,10; 8&9,10	5&9; 6&9; 8&9
July 1995	3&9; 5&9; 6&9; 7&9; 8&9	3&9; 5&9; 6&9; 7&9; 8&9	3&9; 5&9; 6&9; 7&9; 8&9
October 1995	5&10; 6&10; 7&10; 8&10	5&10; 6&10; 7&10; 8&10	5&10; 6&10; 7&10; 8&10
January 1996	NS	NS	NS
April 1996	3&10; 6&10; 7&10; 8&10; 9&10	3&10; 6&10; 7&10; 8&10; 9&10	3&10; 6&10; 7&10; 8&10; 9&10

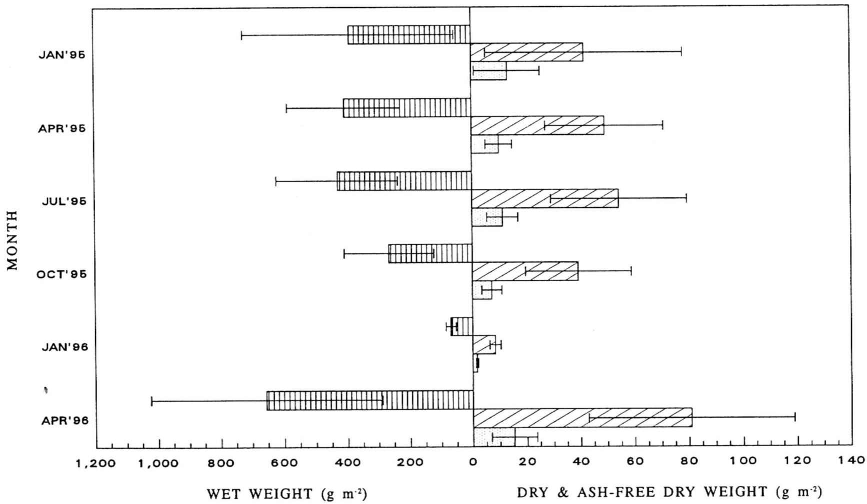
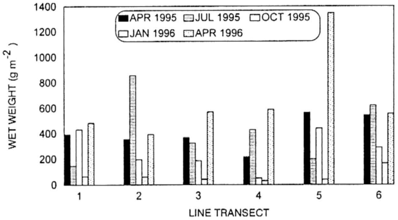
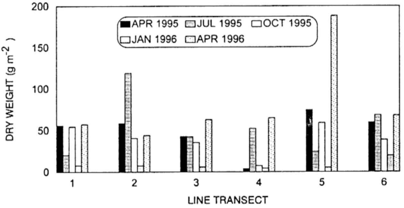


Figure 27. Seasonal variation in biomass of *S. swartzii* with standardard deviation bars.





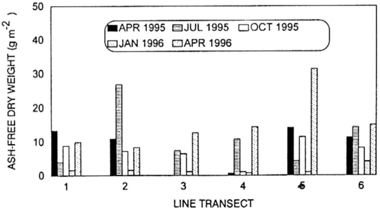


Figure 28. Biomass of *S. swartzii* for every destructive sampling from April 1995 to April 1996.

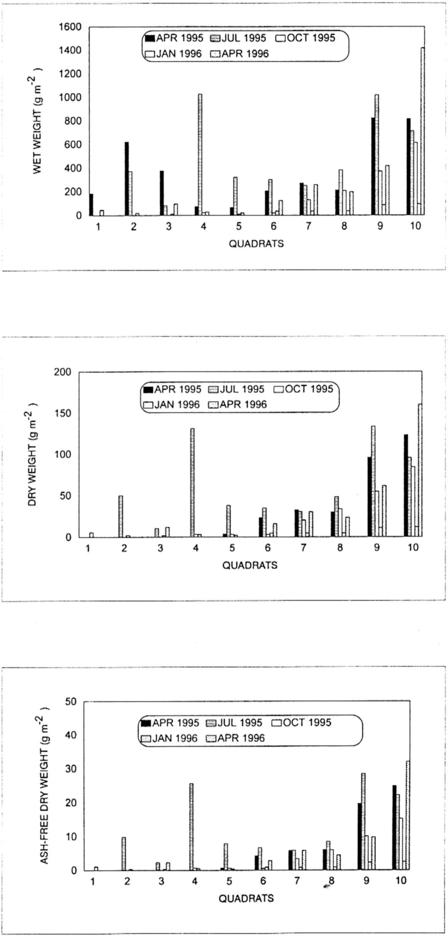


Figure 29. Biomass of *S. swartzii* between station levels (quadrats) from April 1995 to April 1996.

4.4.2.4 Comparison Between Biomass and Mean Thallus Length

Figure 30 (Appendix 11) shows the comparison between the mean thallus length and biomass of *S. swartzii*.

The peak period of mean thallus length coincided with the highest biomass (Figure 30). Correlation analysis indicated that a strong positive correlation between the mean thallus length and the wet weight ($r = 0.9275$, $p \leq 0.05$), dry weight ($r = 0.9496$, $p \leq 0.05$) and ash-free dry weight ($r = 0.8593$, $p \leq 0.05$).

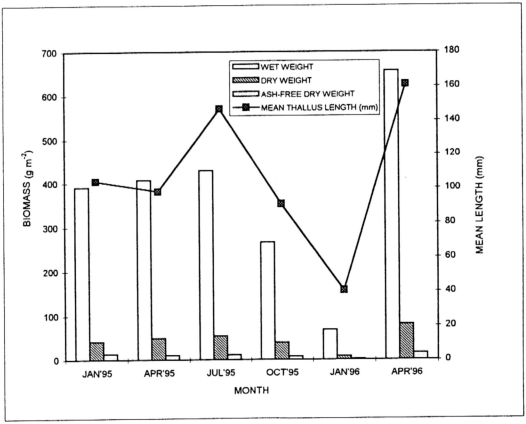


Figure 30. Comparison between mean thallus length (mm) and biomass (g m^{-2}) of *S. swartzii*.

The mean thallus length between line transects (Figure 31, Appendix 14b) showed a similar trend to the biomass between line transects (Figure 28).

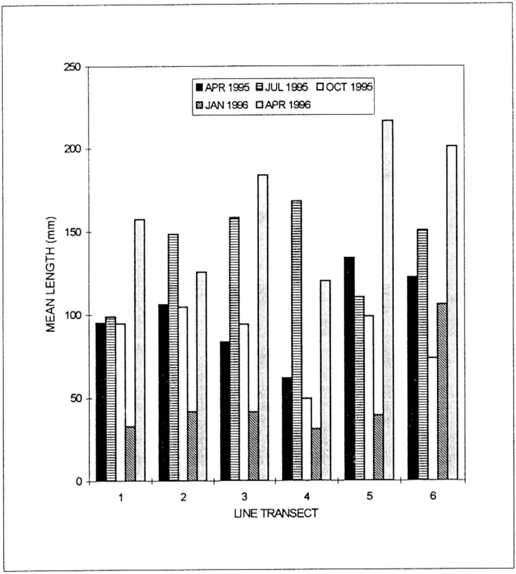


Figure 31. Mean length (mm) of *S. swartzii* for every destructive sampling from April 1995 to April 1996.

4.4.2.5 Seasonal Variation in Length Classes

The seasonal change in the structure of individuals in various length classes are depicted in Figures 32 and 33 (Appendix 15 & 16). In the *S. swartzii* population, the average length was 107.24±74.17 mm with 89% of the population shorter than 199 mm (Figure 32, Appendix 15b). Out of this, 54% of the population was shorter than 99 mm.

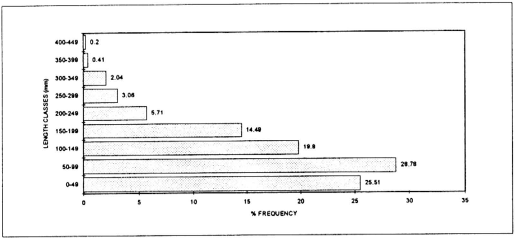
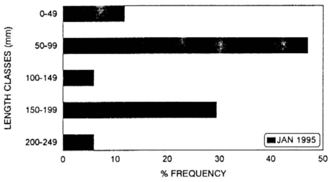
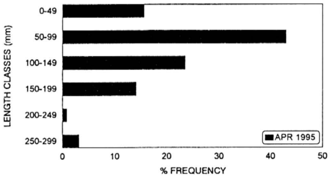


Figure 32. Length classes of *S. swartzii.*

Figure 33 (Appendix 16b) shows the distribution of *S. swartzii* population for every sampling period. Most of the plants were found in the length classes of 50 - 99 mm in January 1995 (47%) and April 1995 (43%). In July 1995, 28% of the population was found in length classes of 100 - 149 mm. In October 1995 and January 1996, most plants were found in the length classes of 0 - 49 mm with a percentage of 35% and 71%, respectively. Most plants (25%) were found in the length classes of 100 - 149 mm in April 1996.





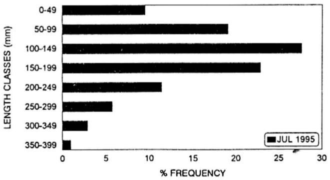
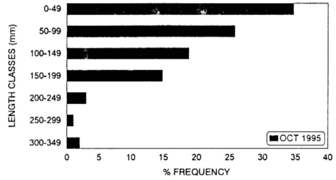
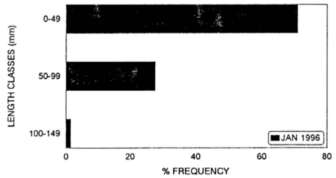


Figure 33. Percentage frequency of *S. swartzii* in various length classes for every destructive sampling.





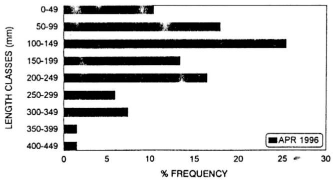


Figure 33. Percentage frequency of *S. swartzii* in various length classes for every destructive sampling (continued).

4.4.2.6 Comparison Between Percentage Fertility with Biomass and Mean Thallus Length

The population was fertile throughout the sampling period with the lowest percentage fertility in January 1996 (4.17%) as shown in Figures 34 (Appendix 11) and 35. The increase in the percentage fertility was followed by the increase in the biomass (Figure 34). The percentage fertility of the population was strongly correlated with the wet weight ($r = 0.7770$, $p \leq 0.05$), dry weight ($r = 0.8673$, $p \leq 0.05$) and ash-free dry weight ($r = 0.6267$, $p \leq 0.05$).

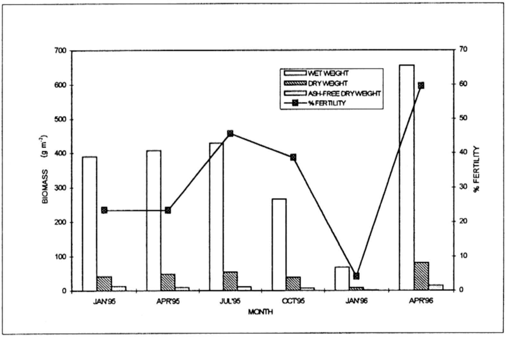


Figure 34. Comparison between percentage fertility and biomass for *S. swartzii*.

Similar pattern was observed between the percentage fertility and mean thallus length, where peak percentage fertility coincided with the longest thallus length as shown in Figure 35. The percentage of fertile plants was found to be significantly correlated with the mean thallus length ($r = 0.8959$, $p \leq 0.05$).

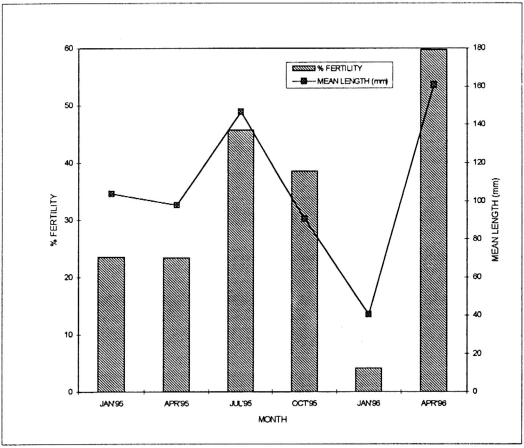


Figure 35. Comparison between percentage fertility and mean thallus length (mm) for *S. swartzii*.

4.5 Environmental Parameters

Figures 36 and 38 give the trend of the environmental parameters (salinity, water temperature, dissolved oxygen and pH) and nutrients (ammonia, nitrate and phosphate) for Cape Rachado, Port Dickson throughout the monitoring period (January 1995 to April 1996), respectively. Figure 37 gives the trend of ambient temperature, sunshine, solar radiation and rainfall for Malacca. All the means are given in Appendix 17.

4.5.1 Salinity

Highest salinity was recorded in June 1995 at 32‰ and the lowest in August 1995 at 26 ‰. The trend as shown in Figure 36, indicated that the salinity was rather stable from January 1995 to June 1995 and started to fluctuate thereafter until February 1996. Overall, the fluctuation of salinity was relatively small, and the salinity was maintained at 30 - 31 ‰ most of the times over the monitoring period.

4.5.2 Water Temperature

The highest water temperature was recorded in May 1995 at 36°C and the lowest in February 1996 at 28.7°C (Figure 36). The water temperature was relatively high from April 1995 to October 1995 except for a drop in September 1995. Then, it decreased gradually till February 1996 and increased thereafter.

4.5.3 Dissolved Oxygen

The fluctuation of dissolved oxygen was relatively high over the monitoring period (Figure 36), May 1995 being the highest (14.3 mg l^{-1}) and the lowest in April 1996 (7.3 mg l^{-1}).

4.5.4 pH

The pH rose gradually from January 1995 to a peak value of 8.83 in May 1995. Then, it dropped to the lowest value of 7.13 in July 1995. The pH started to fluctuate thereafter (Figure 36).

4.5.5 Ambient Temperature

The trend of the maximum and minimum air temperature was shown in Figure 37. They were relatively constant throughout the monitoring period. The highest mean maximum air temperature was recorded in March 1995 at 33.0°C and the lowest in December 1995 at 30.2°C. The highest mean minimum air temperature was recorded in June 1995 at 24.3°C and the lowest in January 1996 at 22.8°C. There was a range of 10.2°C between the highest mean maximum air temperature and the lowest mean minimum air temperature.

4.5.6 Sunshine

Mean number of hours of sunshine per day peaked in March 1995 (7.8 hours) and were at their lowest in December 1995 at 3.4 hours (Figure 37). There was a relatively higher number of hours of sunshine per day between March 1995 to June 1995, and February 1996 to April 1996.

4.5.7 Solar Radiation

The highest radiation was recorded in March 1995 at 19.65 MJm^{-2} and the lowest in February 1996 at 9.04 MJm^{-2} (Figure 37). Data from September 1995 to January 1996 was not available.

4.5.8 Rainfall

The highest rainfall was recorded in September 1995 at 407 mm and the lowest in January 1996 at 22.8 mm. Figure 37 indicated that the rainfall was relatively higher from May 1995 to December 1995 except a drop in June and October 1995 compared to the other months of the monitoring period.

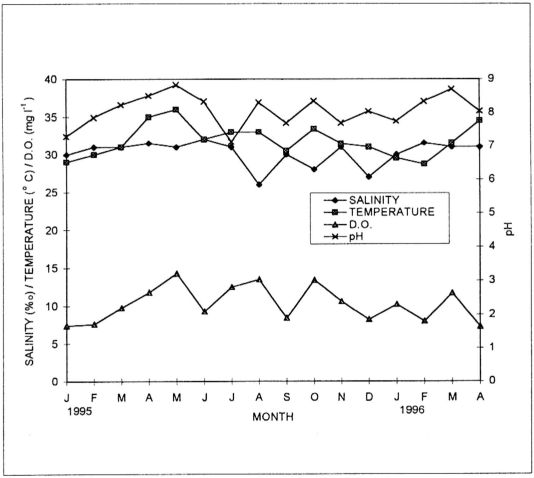


Figure 36. Salinity (‰), water temperature (°C), dissolved oxygen (mg l^{-1}) and pH for Cape Rachado, Port Dickson.

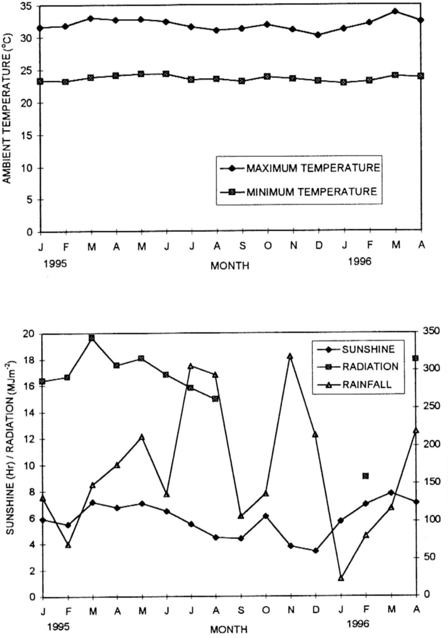


Figure 37. Ambient temperature (maximum and minimum air temperatures, °C), sunshine hours, solar radiation (MJm^{-2}) and rainfall (mm) for Malacca.

4.5.9 Nutrient Levels

Figure 38 shows the general trend of ammonia, nitrate and phosphate levels throughout the monitoring period.

A high level of ammonia was recorded from August 1995 to January 1996 with a range of 3.82 - 7.53 μg L-1, and generally a lower level was obtained from March to July 1995 and February to April 1996.

A relatively high fluctuation was observed in the trend of nitrate from March 1995 to March 1996 with the lowest value of 0.08 μg L^{-1} in April 1995 and the highest value of 62.08 μg L^{-1} in January 1996.

The trend for phosphate level was rather constant throughout the monitoring period except for a peak which was observed in December 1995 with a value of 85.84 μg L^{-1} .

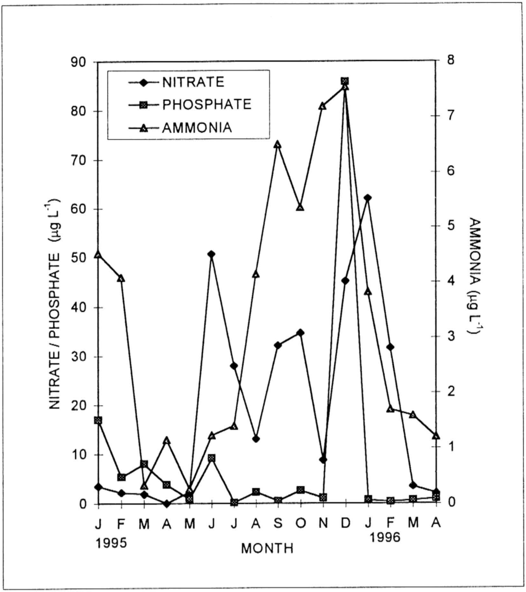


Figure 38. Nutrients (ammonia, nitrate and phosphate, µg L^{-1}) for Cape Rachado, Port Dickson.

4.6 Correlation with Environmental Parameters

4.6.1 Permanent Quadrats

Table 12 gives the correlation coefficient (r values) from the simple correlation analysis and Table 13 gives the values of the best cross-correlation coefficient with the lag period between *S. baccularia* and *S. swartzii* growth rate, degenerative rate, mean thallus length and number of plants bearing receptacles with environmental parameters.

4.6.1.1 Growth Rate

Increased growth of *S. baccularia* plants was only influenced by the increase in minimum ambient temperature (r = 0.6567) and the decrease in ammonia level (r = -0.6449) as shown in Table 12.

Cross-correlation analysis (Table 13) shows that the increased growth of *S. baccularia* plants was significantly correlated with the increase of rainfall (r = 0.6485) three months before.

Simple correlation analysis (Table 12) shows the increase growth of *S. swartzii* plants was significantly correlated with the increase in maximum ambient temperature (r = 0.6863) and sunshine (r = 0.6435), and decrease in radiation (r = -0.5869) and ammonia level (r = -0.5957).

Cross-correlation analysis (Table 13) shows that the increased growth of *S. swartzii* was significantly correlated with the increase of maximum air temperature (r = 0.6863) and sunshine (r = 0.6435) of that month, and rainfall (r = 0.5252) two months before. Analysis also showed that increased growth of the plants was significantly correlated with the decrease of radiation (r = -0.5869) and ammonia (r = -0.5957) of that month.

4.6.1.2 Degenerative Rate

Degenerative rate of *S. baccularia* and *S. swartzii* plants was not influenced by any of the environmental parameters recorded in this investigation except for dissolved oxygen in *S swartzii* plants (r = -0.5770) as shown in Table 12.

However, the cross-correlation analysis (Table 13) shows that the degenerative rate of *S. baccularia* plants was significantly correlated with the increase of sunshine (r = 0.5043, lag period = 6 months before), and the decrease of water temperature and dissolve oxygen (r = -0.6869 and

-0.6534, respectively, lag period = 2 months before), and rainfall (r = -0.5478, lag period = 3 months before).

Degenerative rate of *S. swartzii* plants was found significantly correlated with the decrease of water temperature and dissolve oxygen (r = -0.6004 and -0.5950, respectively, lag period = 2 months before) as shown in Table 13.

4.6.1.3 Mean Thallus Length

Increased in the thallus length for both *Sargassum* species was influence by the decrease in the nitrate level (r = -0.4992 for *S. baccularia* and r = -0.5358 for *S. swartzii*) as shown in the simple correlation analysis (Table 12).

Mean thallus length for both *Sargassum* species was significantly influenced by the increase of water temperature three months before and solar radiation two month before, and minimum air temperature four months before for *S. baccularia* and three months before for *S. swartzii* (Table 13). Nutrients level in the seawater did not show significant influence towards the mean thallus length of *S. baccularia* plants but significant correlation was found between the mean thallus length of

S. swartzii and nitrate level (r = -0.5645, lag period = 2 months before) as shown in Table 13.

4.6.1.4 Reproductive State

Simple correlation analysis (Table 12) shows that the reproductive state of both *Sargassum* species was not influenced by any of the environmental parameters in this study. However, significant correlation with some of the environmental parameters with a lag period was shown in the cross-correlation analysis (Table 13).

Number of plants bearing receptacles for *S. baccularia* was significantly influenced by the increase of water temperature (r = 0.5191, lag period = 3 months before) and phosphate level (r = 0.5354, lag period = 4 months before), and the decrease in solar radiation (r =-0.5224, lag period = 6 months before) as shown in the cross-correlation analysis (Table 13).

As for *S. swartzii*, the number of plants bearing receptacles was only significantly influenced by the increase of water temperature two months before (r = 0.5847) and the decrease of nitrate level two months before (r = -0.5046) as shown in Table 13.

Table 12. Correlation between *Sargassum* growth rate, degenerative rate, mean thallus length (TL) and number of plants bearing receptacles (F) with environmental parameters ($p < 0.05$).

Environmental parameters	Growth rate		Degenerative rate	
	S. baccularia	*S. swartzii*	*S. baccularia*	*S. swartzii*
Salinity	0.4714	0.1372	-0.2088	0.0403
Temperature	0.3789	0.2026	-0.0274	-0.0793
D.O.	0.0602	0.3989	0.1457	*-0.5770
pH	0.3999	0.3604	-0.2465	-0.0782
Minimum Temperature	*0.6567	0.3712	-0.4010	-0.3510
Maximum Temperature	*0.4893	*0.6863	-0.3130	-0.1913
Radiation	0.2416	*-0.5869	-0.2995	-0.3855
Sunshine	*0.4952	*0.6435	-0.2599	-0.2282
Rainfall	-0.2499	-0.0629	0.1228	-0.0002
Ammonia	*-0.6449	*-0.5957	0.3380	0.2943
Nitrate	-0.3003	-0.2821	0.1907	0.1353
Phosphate	-0.1864	-0.3611	0.1824	0.2498
Environmental parameters	TL		F	
	S. baccularia	*S. swartzii*	*S. baccularia*	*S. swartzii*
Salinity	0.2128	0.2200	-0.2219	-0.0563
Temperature	-0.1902	-0.2781	-0.1112	-0.0996
D.O.	-0.3593	-0.3443	-0.0980	-0.1401
pH	-0.2833	-0.1314	-0.2957	-0.0378
Minimum Temperature	0.0725	0.0992	-0.1838	0.2021
Maximum Temperature	0.1527	0.3849	-0.2286	0.2069
Radiation	0.2782	0.2461	-0.0230	0.3360
Sunshine	0.1972	0.3813	-0.2200	-0.1731
Rainfall	-0.2401	-0.3285	-0.0202	-0.1369
Ammonia	-0.1731	-0.2545	0.0465	-0.1263
Nitrate	*-0.4992	*-0.5358	-0.2596	-0.3587
Phosphate	-0.0809	-0.0854	-0.1009	-0.1686

Table 13. Cross-correlation between *Sargassum* growth rate, degenerative rate, mean thallus length (TL) and number of plants bearing receptacles (F) with environmental parameters. Correlation for each species with each each factor is given with the lag period yielding the best correlation ($p < 0.05$). 1 lag period = 1 month.

Environmental parameters	Growth rate				Degenerative rate			
	S. baccularia	Time lag	*S. swartzii*	Time lag	*S. baccularia*	Time lag	*S. swartzii*	Time lag
Salinity	-0.4744	-6	0.4569	1	-0.3881	-1	-0.4290	3
Temperature	*-0.5345	5	0.4554	6	*-0.6869	-2	*-0.6004	-2
D.O.	*-0.5053	4	-0.4394	6	*-0.6534	-2	*-0.5950	-2
pH	0.3999	0	-0.4126	-4	0.3137	-1	0.2664	-1
Minimum Temperature	*0.6567	0	*-0.5181	6	-0.4010	0	-0.3602	-2
Maximum Temperature	*0.6035	1	*0.6863	0	0.3907	-6	-0.4888	3
Radiation	0.4334	1	*-0.5869	0	-0.4192	-1	-0.4506	-2
Sunshine	*0.6485	1	*0.6435	0	*0.5043	-6	*-0.5259	3
Rainfall	*0.7534	-3	*0.5252	-2	*-0.5478	-3	0.4523	4
Ammonia	*-0.7073	1	*-0.5957	0	0.4841	2	*0.6104	3
Nitrate	*-0.5421	1	-0.2821	0	*0.5725	1	0.4000	1
Phosphate	0.4576	-6	*0.628	3	-0.4569	-6	0.2803	-5

Environmental parameters	TL				F			
	S. baccularia	Time lag	*S. swartzii*	Time lag	*S. baccularia*	Time lag	*S. swartzii*	Time lag
Salinity	0.2878	-1	0.3056	-1	0.3166	2	0.3358	4
Temperature	*0.6863	-3	*0.6418	-3	*0.5191	-3	*0.5847	-2
D.O.	-0.3593	0	-0.3443	0	0.3867	-3	0.4133	-2
pH	-0.3893	-6	-0.3730	-6	*-0.5173	1	-0.3578	-1
Minimum Temperature	*0.5578	-4	*0.5899	-3	0.4692	2	0.3610	-2
Maximum Temperature	0.3819	-2	0.3849	0	0.3622	3	0.3170	3
Radiation	*0.6155	-2	*0.5814	-2	*-0.5224	-6	0.4888	-2
Sunshine	0.3151	-2	0.3813	0	0.3795	3	0.3804	2
Rainfall	0.4732	-6	0.4902	-6	0.3176	-1	0.4260	-6
Ammonia	-0.4744	-2	-0.4285	-2	-0.4048	3	-0.4819	3
Nitrate	-0.4992	0	*-0.5645	-2	-0.4318	-3	*-0.5046	-2
Phosphate	-0.1494	-1	0.3536	3	*0.5354	-4	-0.2434	-1

4.6.2 Quarterly Destructive Sampling

Table 14 gives the correlation coefficient (r values) from simple correlation analysis and Table 15 gives the values of the best cross-correlation coefficient with the lag period between *S. baccularia* and *S. swartzii* biomass, mean thallus length and number of plants bearing receptacles with environmental parameters.

4.6.2.1 Biomass

Increase in biomass of *S. baccularia* population was significantly influenced by the increase in rainfall and phosphate level (except for dry weight) and the decrease in pH and radiation as shown in the simple correlation analysis (Table 14).

However, biomass of *S. baccularia* population was significantly influenced by all the environmental parameters with a lag period as shown in cross-correlation analysis (Table 15) except for wet weight where ammonia level did not show significant correlation. Increase in the biomass was significantly influenced by the increase of minimum air temperature three months before (except for dry weight), rainfall of that month and nitrate level six months before. It was significantly influenced by the decrease of pH and solar radiation of that month and sunshine six months before

Simple correlation analysis (Table 14) shows increase in biomass of *S. swartzii* population was significantly correlated to the increase in salinity (except for dry weight and ash-free dry weight), water temperature (except for ash-free dry weight), ambient temperature, sunshine and rainfall and the decrease in ammonia (except for ash-free dry weight) and nitrate levels.

Cross-correlation analysis shows that wet weight and dry weight of *S. swartzii* population was significantly influenced by the environmental parameters with a lag period (Table 15) except for the dissolved oxygen and phosphate level. As for ash-free dry weight, significant correlation was not found with the water temperature, minimum air temperature and phosphate level.

4.6.2.2 Mean Thallus Length

Increase in the mean thallus length of *S. baccularia* plants was significantly correlated to the increase in phosphate level ($r = 0.6254$) and the decrease in pH ($r = -0.7074$), radiation ($r = -0.7554$) and sunshine ($r = -0.4766$) as shown in Table 14.

Cross correlation analysis (Table 15) shows mean thallus length of *S. baccularia* population was significantly influenced by the increase of minimum air temperature three months before, rainfall and phosphate level of that month, and the decrease of sunshine six months before, pH and solar radiation of that month.

Increase in mean thallus length of *S. swartzii* population was strongly influenced by the increase in rainfall (r = 0.9104) and water temperature (r = 0.5914), and decrease in ammonia (r = -0.6232) and nitrate (r = -0.6241) level as shown in Table 14.

Table 15 shows the increase in mean thallus length of *S. swartzii* population was significantly influenced by the increase of dissolved oxygen three months before, water temperature, rainfall and nitrate level of that month.

4.6.2.3 Reproductive State

Simple correlation analysis (Table 14) shows the increase in reproductive state of *S. baccularia* population was strongly influenced by the increase in rainfall (r = 0.7619) and decrease in pH (r = -0.5806) and ammonia level (r = - 0.5200).

Cross-correlation analysis (Table 15) shows the reproductive state of *S. baccularia* population was significantly influenced by the antecedent water temperature, minimum and maximum air temperature, and sunshine.

The increase in the reproductive state of *S. swartzii* plants was strongly influenced by the environmental parameters especially the increase in rainfall (r = 0.8686), water temperature (r = 0.8040) and minimum ambient temperature (r = 0.6401) as shown in Table 14. However, the cross-correlation analysis (Table 15) shows strong correlation with a lag period for other environmental parameters, such as ammonia level (r = 0.7718, lag period = one month before), nitrate level (r = 0.7121, lag period = one month before) and sunshine (r = -0.7413, lag period = one month before).

Table 14. Correlation between *Sargassum* biomass, TL and F with environmental parameters ($p < 0.05$).

Environmental parameters	Wet Weight		Dry Weight		Ash-free Dry Weight	
	S. baccularia	*S. swartzii*	*S. baccularia*	*S. swartzii*	*S. baccularia*	*S. swartzii*
Salinity	0.3679	*0.4997	0.4550	0.4198	0.2704	0.4139
Temperature	-0.2059	*0.5798	0.0959	*0.6775	-0.2010	0.3632
D.O.	-0.1186	-0.4027	0.0260	-0.2797	-0.0764	-0.4782
pH	*-0.6864	0.0072	*-0.6101	0.0831	*-0.7391	-0.1643
Minimum Temperature	0.0008	*0.5669	0.1670	*0.6229	-0.0266	0.4857
Maximum Temperature	-0.0995	*0.6638	0.0568	*0.6858	-0.1657	*0.5314
Radiation	*-0.6658	0.3234	*-0.5962	0.3424	*-0.7301	0.1288
Sunshine	-0.3553	*0.6390	-0.2434	*0.6457	-0.4174	0.4823
Rainfall	*0.5370	*0.7529	*0.7987	*0.7854	*0.5917	*0.7069
Ammonia	-0.1856	*-0.6228	-0.4103	*-0.6105	-0.1329	-0.4452
Nitrate	-0.4543	*-0.8343	-0.4821	*-0.7700	-0.3931	*-0.8886
Phosphate	0.5673	0.0560	0.2777	-0.0712	*0.5156	0.3469

Environmental parameters	TL		F	
	S. baccularia	*S. swartzii*	*S. baccularia*	*S. swartzii*
Salinity	0.2044	0.4236	0.4457	0.1087
Temperature	-0.3179	*0.5914	0.1596	*0.8040
D.O.	-0.0588	-0.1778	-0.4030	0.4074
pH	*-0.7074	-0.1666	*-0.5806	0.1194
Minimum Temperature	-0.0696	0.4622	-0.0374	*0.6401
Maximum Temperature	-0.2201	0.4767	0.0364	0.4865
Radiation	*-0.7554	0.0718	-0.1822	0.0017
Sunshine	*-0.4766	0.3888	0.0588	0.2559
Rainfall	0.4313	*0.9104	*0.7619	*0.8686
Ammonia	-0.0080	*-0.6232	*-0.5200	-0.4587
Nitrate	-0.3482	*-0.6241	-0.3722	-0.3370
Phosphate	*0.6254	-0.1419	-0.0492	-0.4482

Table 15. Cross-correlation between *Sargassum* biomass, TL and F with environmental parameters. Correlation for each species with each factor is given with the lag period yielding the best correlation ($p < 0.05$). 1 lag period = 3 months

Environmental parameters	Wet Weight				Dry Weight				Ash-free Dry Weight			
	S. baccularia	Time lag	*S. swartzii*	Time lag	*S. baccularia*	Time lag	*S. swartzii*	Time lag	*S. baccularia*	Time lag	*S. swartzii*	Time lag
Salinity	*0.5104	1	*-0.8318	2	*0.6758	1	*-0.7940	2	*0.5934	1	*-0.7288	2
Temperature	*-0.5759	2	*0.5798	0	*-0.6401	2	*0.6775	0	*-0.5744	2	0.3697	1
D.O.	*0.6604	-1	0.4937	-1	*0.7493	-1	0.4758	-1	*-0.6703	2	*0.5640	-1
pH	*-0.6864	0	*-0.6452	3	*-0.6101	0	*-0.7098	3	*-0.7391	0	*-0.5891	3
Minimum Temperature	*0.6451	-1	*-0.5718	1	*-0.5632	-2	*0.6229	0	*0.5944	-1	0.4857	0
Maximum Temperature	*-0.5732	-2	*0.6638	0	*-0.5856	-2	*0.6858	0	*0.6108	1	*-0.5452	3
Radiation	*-0.6658	0	*-0.5971	3	*-0.5962	0	*-0.6451	3	*-0.7301	0	*-0.5214	3
Sunshine	*-0.6894	-2	*0.6390	0	*-0.5913	-2	*0.6457	0	*-0.6334	-2	*-0.5247	3
Rainfall	*0.5370	0	*0.7529	0	*0.7987	0	*0.7854	0	*0.5917	0	*0.7069	0
Ammonia	-0.3900	1	*0.7842	2	*0.5241	2	*0.7570	2	*-0.5079	1	*0.7182	2
Nitrate	*0.5842	-2	*-0.8343	0	*0.6635	-2	*-0.7700	0	*0.5694	-2	*-0.8886	0
Phosphate	*0.6303	2	-0.3769	3	*0.7936	2	-0.2751	3	*0.6925	2	0.3469	0

Environmental parameters	TL				F			
	S. baccularia	Time lag	*S. swartzii*	Time lag	*S. baccularia*	Time lag	*S. swartzii*	Time lag
Salinity	*0.5045	1	*-0.7455	2	*-0.7429	2	*0.7836	1
Temperature	*-0.5241	2	*0.5914	0	-0.4681	-2	*0.8040	0
D.O.	*-0.6598	2	*0.5342	-1	-0.4030	0	*0.5028	-1
pH	*-0.7074	0	*-0.6214	3	*-0.5806	0	*-0.6301	3
Minimum Temperature	*0.6074	-1	0.4622	0	*-0.5582	-2	*0.6401	0
Maximum Temperature	*0.6070	1	*-0.5315	3	-0.4674	-2	*-0.6880	-1
Radiation	*-0.7554	0	*-0.5606	3	*0.5523	1	*-0.5646	-1
Sunshine	*-0.6312	-2	*-0.5382	3	0.4681	-3	*-0.7413	-1
Rainfall	0.4314	0	*0.9104	0	*0.7619	0	*0.8686	0
Ammonia	-0.4395	1	*0.8021	2	*0.8069	2	*0.7718	-1
Nitrate	*-0.5971	1	*0.6241	0	-0.4499	-3	*0.7121	-1
Phosphate	*0.6254	0	*0.5089	2	*0.5319	2	*0.5820	2