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Seasonal changes in the growth and reproduction of *Sargassum polycystum* C. Ag. and *Sargassum siliquosum* J. Ag. (Sargassaceae, Fucales) from Liloan, Cebu, in Central Philippines

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A *Sargassum* community in Liloan, Cebu, central Philippines comprises two species (*S. polycystum* and *S. siliquosum*) and shows both seasonal and spatial variation in length of primary lateral branches and standing crop. Seasonal patterns were most distinct in the subtidal zone (area of *S. siliquosum*) than in the intertidal. The periods of maximum length (*S. polycystum*=26.71 cm; *S. siliquosum*=54.53 cm) and biomass (*S. polycystum*=3.07 kg wet wt.m^{-2}; *S. siliquosum*=6.61 kg wet wt.m^{-2}) are influenced by the presence of receptacle-bearing branches of each species; premature decline in length and standing crops before growth peaks is attributed to cropping by wave impacts caused by the seasonal occurrence of northeastern monsoon wind. The population of *S. polycystum* tends to have lower values in both length of primary lateral branches and standing crop compared to the *S. siliquosum* population.

Key Index Words: intertidal population—phenology—Philippines—Sargassum polycystum—Sargassum siliquosum—*standing crop—subtidal population.*

The identification of the species originally referred to as *S. myriocystum* in Largo and Ohno (1992) is presently changed herein as *Sargassum polycystum* C. Agardh based on the description of the species in the recently published taxonomic work on the genus *Sargassum* from the Philippines by Trono (in Abbott 1992), therefore, the latter was used as the proper name for this study.

Sargassum spp. form the dominant vegetation structure in the shallow, coastal waters of the Philippine Islands serving as an important habitat and spawning-ground for many marine organisms, eg. fishes, crustaceans, molluscs, etc. Realizing the importance of *Sargassum* beds led the Philippine local government conservation departments to propose to include their protection in environmental legislation in addition to coral reefs, seagrass beds and mangrove ecosystems. These important marine resources are under enormous ecological pressure from coastal habitation and infrastructure development which, if not properly addressed, could lead to their eventual destruction.

A number of phenological studies have been made on the bed-forming species of *Sargassum* in the Philippines (Ang 1982, 1985; Ang and Trono 1987; Ohno *et al.* 1987; Ohno *et al.* 1989). These works were either mostly conducted on *Sargassum* communities in Luzon areas or are conducted only part of the year. This paper is a supplement to the first phase of a phenological study conducted in 1988-1989 on the *Sargassum* community in Liloan, Cebu, central Philippines (Largo and Ohno 1992), in which the present includes data on standing crop not previously included. The study hopes to provide more basic in-

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formation in answer to calls for effective management of local seaweed resource in the Philippines.

Materials and Methods

The study was conducted monthly from February 1989 to January 1990 in Liloan, Cebu, central Philippines, as shown in Figure 1. Five $0.25\,m^2$ quadrats were laid equidistantly across the *Sargassum* bed which is 40 m wide from the shoreward to the seaward edge. The quadrats were laid on dense patches of *Sargassum* which had a maximum cover of not less than 80%. Standing crops were obtained by carefully removing all *Sargassum* thalli, including their holdfasts from each quadrat. Standing crop data are presented as kg wet wt.m^{-2}. Measurements of primary lateral length were made from 10 randomly selected individuals of each species from all quadrat. The values are presented here as monthly average lengths, together with their Standard Deviation (SD) values presented by vertical bars. Fruiting was determined by noting the presence or absence of receptacles on each of the primary lateral branches. Reproductive index is expressed as the percentage of branches with receptacles of the total number of primary lateral branches in 10 *Sargassum* individuals (for each species). Incomplete branches, either damaged by wave action or by natural decay due to old age, were also determined from the same individuals and are expressed as percentage of the total number of branches from 10 individuals.

Water temperature was measured using a mercury-filled thermometer while salinity was measured with an Atago refractometer (accuracy$\pm$1). Both measurements were made in the lower region of the tidal zone every sampling period to avoid extreme values in the shallower regions.

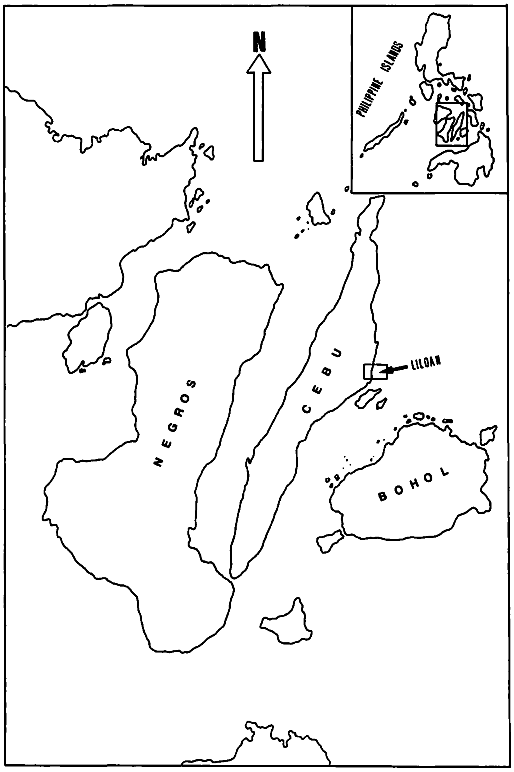

Fig. 1. Map of the study area. (Scale=1 : 10,000)

Results

Zonation pattern within the Sargassum *community*

The vertical zonation of the *Sargassum* bed at Liloan, Cebu, central Philippines is shown in Figure 2 (see also Largo and Ohno 1992). The *Sargassum* community, in the study area is about 40 m wide and comprises two species, *S. polycystum* C. Agardh and *S. siliquosum* J. Agardh, forming two distinct populations, occupying the intertidal and upper subtidal zones, respectively. The intertidal area experiences long exposures to the atmosphere at low tide; here *S. polycystum* is dominant. The subtidal population composed of *S. siliquosum*, on the other hand, may be exposed partly only during extreme low spring tides. From late August to mid-November the study area was particularly exposed to the Northeast monsoon wind which caused the two populations to be subjected from weak to strong wave actions depending on depth. Wave action is reduced during the rest of the year.

Monthly water temperatures during the study period ranged from 26.8°C in June to 32.0°C in March (Table 1) while salinity fluctuated between 34 and 35.

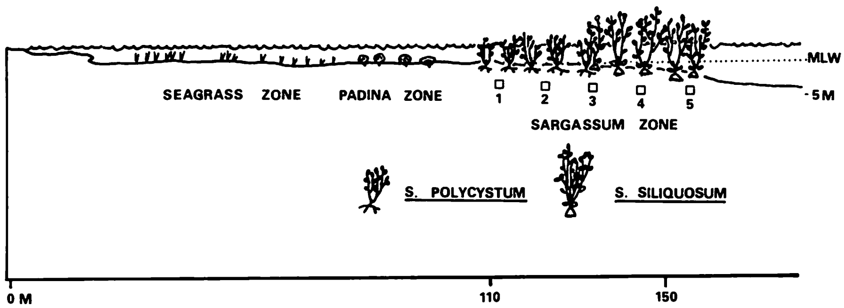

Fig. 2. Zonation pattern of *Sargassum* populations in the study area. Numbered squares represent the quadrat zones.

Growth patterns of the Sargassum *populations*

Monthly average lengths of the primary lateral branches of the *Sargassum* populations varied between quadrat-zones (Fig. 3). *S. polycystum* population (Q1 and Q2) showed lower monthly average length values in contrast to *S. siliquosum* population (Q3, Q4 and Q5). Thalli in Quadrat 1 (located in the shoreward edge of the bed) had monthly average length values ranging from a minimum of 4.00 ± 2.21 cm in June to a maximum of 27.72 ± 2.32 cm in April. The minimum in June was followed by relatively small fluctuations of ± 5 cm until December. Longer plants began to occur in January.

S. polycystum in Quadrat 2 also showed a fluctuating pattern of monthly average lengths from March (no data in February) to the last sampling period in January when they attained their maximum (30.00 ± 11.39 cm). The lowest monthly average length value in this zone was in April (8.58 ± 4.92 cm).

In the subtidal zone, monthly measurements showed plants in all three quadrats to increase in monthly average length values towards May. Length values fluctuated thereafter and all three quadrats attained an almost uniform length in November (34 to 38 cm). Thalli in all three quadrats then increased slightly in monthly average length towards December as the *S. siliquosum* plants became fully mature (highest receptacle occurrence). In the following month, thalli in all quadrats declined in length apparently due to decay.

Population growth based on standing crop measurements, in the same quadrat-zones, likewise revealed lower biomass values in the intertidal zone (Q1 and Q2) and are significantly different ($P < 0.01$) to those in the deeper subtidal zone (Q3, Q4 and Q5; Fig. 4) based on one-way ANOVA analysis. Quadrats 1 and 2 of *S. polycystum* did not show a well-defined growth pattern but standing crop in Quadrat 1 remained consistently lower than in Quadrat 2 (significant with $P < 0.05$). Both have higher values recorded in February and March (there was no data for Quadrat 1 in the intertidal region for February). From this period until January, no marked increase has been noted except for Quadrat 2 where a peak was recorded in July, when maximum length of primary laterals for *S. polycystum* occurred.

Table 1. Changes in monthly seawater temperature and salinity in the study area, February 1989—January 1990.

Date	TEMP. °C	SALINITY
Feb. 27. 1989	31.0	34
Mar. 31	32.0	34
Apr. 27	31.0	35
May. 24	27.3	35
Jun. 30	26.8	35
Jul. 30	29.2	35
Aug. 25	30.2	35 monsoon season
Sep. 30	31.0	34 monsoon season
Oct. 23	31.0	35 monsoon season
Nov. 24	30.9	35 monsoon season
Dec. 20	30.5	35
Jan. 30. 1990	30.0	35

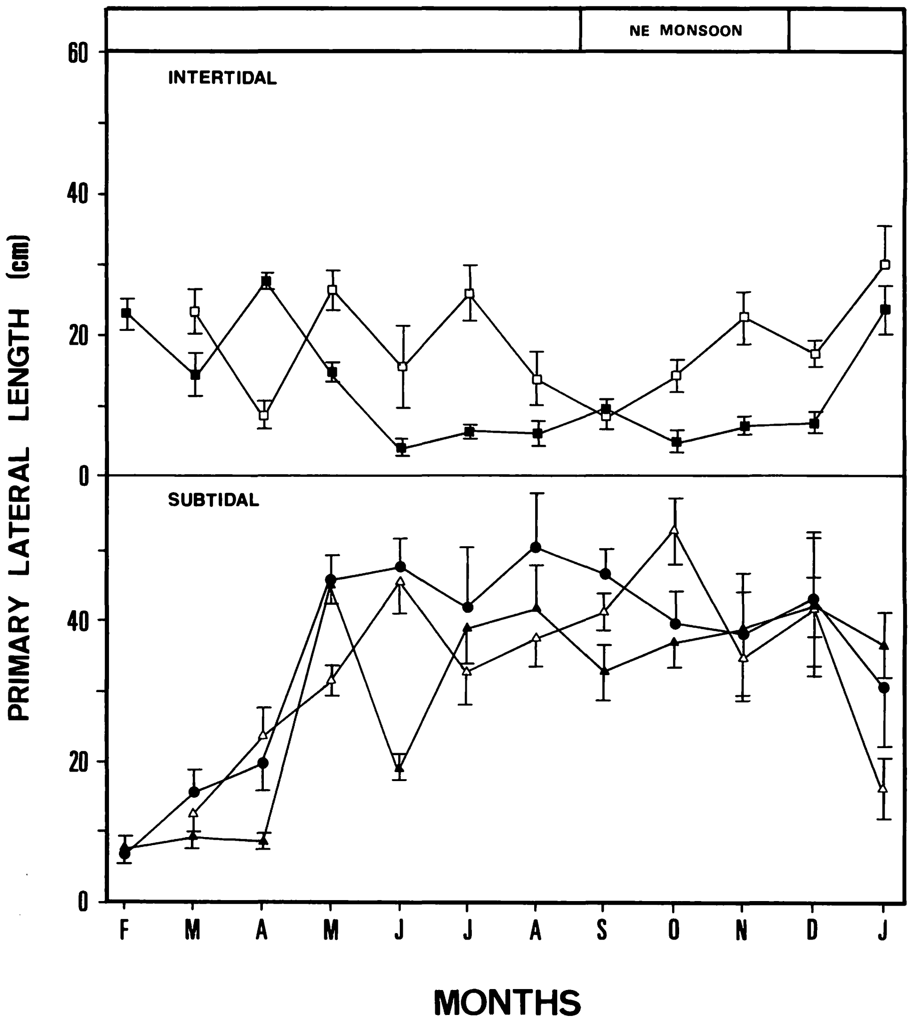

Fig. 3. Variations in monthly average lengths of primary lateral branches between intertidal and subtidal populations of *Sargassum*. Intertidal population = *S. polycystum*, subtidal population = *S. siliquosum*. Quadrat 1 (■), Quadrat 2 (□), Quadrat 3 (▲), Quadrat 4 (△), Quadrat 5 (●). Vertical bars represents Standard Deviation (n = 10).

The average standing crop values for the whole year among subtidal population of *S. siliquosum* for Q3, Q4 and Q5, respectively, were 3.30±1.91, 4.15±1.49 and 3.58±1.98 kg wet wt.m^{-2}, with the highest value in Q4. Monthly measurements showed no significant difference (P=0.05) in standing crop in the three quadrat zones. A decrease from February to March was followed by a dramatic increase towards June, except in Quadrat 3 where it peaked in July; Quadrats 4 and 5 declined at the same time in July. Standing crop in all three quadrats dropped from October to November during the monsoon period. A peak in standing crop was observed for Quandrats 4 and 5 in December with increase in length of the primary laterals and branches with receptacles of *S. siliquosum*. Standing crop in all quadrats dropped abruptly to its lowest in January at the time when decaying thalli of *S. siliquosum* were disintegrated by wave action.

A comparison of Quadrats 1-5 (Table 2) across the *Sargassum* zone showed an increase

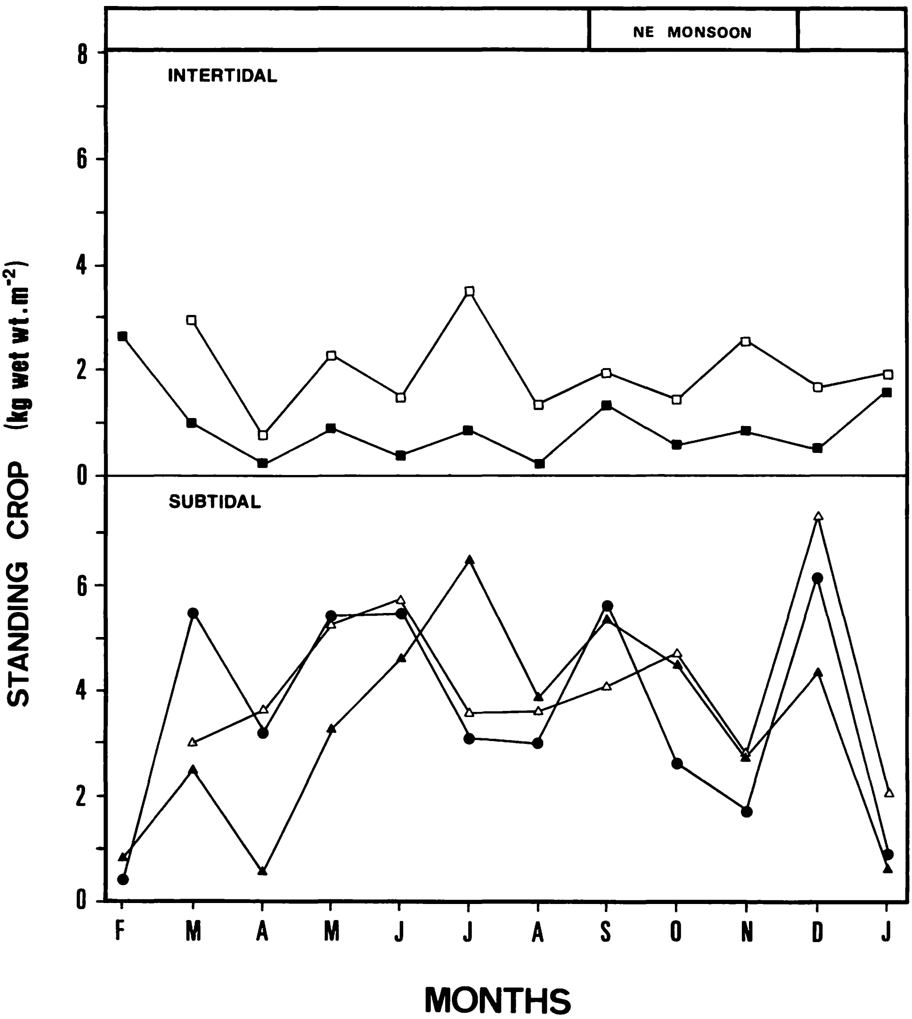

Fig. 4. Monthly variation in the mean standing crop (kg wet wt.m^{-2}) between populations in intertidal and subtidal areas. Quadrat 1 (■), Quadrat 2 (□), Quadrat 3 (▲), Quadrat 4 (△), Quadrat 5 (●).

in biomass from the intertidal towards subtidal zone, except in the last quadrat (Q5) at the deeper edge of the bed with more than 4 m depth. One-way ANOVA test showed a significant difference between the monthly average standing crop ($P < 0.01$) between the five quadrats.

Thalli condition

Increase in percentage of incomplete branches occurred during period of full maturation, when some branches started to decay, and on months with strong wave action caused by the northeast monsoon wind. In *S. polycystum* higher percentage of incomplete branches of up to 75% of branches examined occurred mainly during period of maturity than during the monsoon period (Fig. 5). In *S. siliquosum* cropping by monsoonal waves resulted in higher percentage of incomplete branches than by normal decline as shown in the higher percentage of incomplete branches during the monsoon period (August-November, Fig. 5).

Reproductive Phases

During the study period *Sargassum polycystum* thalli produced reproductive branches

Table 2. Monthly standing crop values of *Sargassum* population in Liloan, Cebu, the Philippines.

Month	Standing Crop (kg wet wt.m^{-2})						
	Quadrat No. 1	2	3	4	5	Ave (Q1&Q2)	Ave. (Q3, Q4, Q5)
Feb. 89	2.65	ND*	0.84	ND	0.44	1.33	0.42
Mar.	0.99	2.91	2.52	3.20	5.49	1.95	3.74
Apr	0.23	0.75	0.57	3.62	3.16	0.49	2.45
May	0.89	2.28	3.28	5.25	5.43	1.59	4.65
Jun	0.36	1.43	4.61	5.72	5.46	0.90	5.26
Jul	0.83	3.49	6.48	3.58	3.09	2.16	4.38
Aug	0.20	1.33	3.85	3.58	3.02	0.77	3.48
Sep	1.29	1.92	5.33	4.07	5.59	1.61	4.70
Oct	0.56	1.39	4.47	4.73	2.60	0.98	3.93
Nov	0.82	2.49	2.71	2.87	1.69	1.66	2.42
Dec	0.50	1.61	4.33	7.27	6.10	1.06	5.90
Jan. 90	1.52	1.87	0.61	1.99	0.87	1.70	1.16

* ND=no data.

from February to May and again, from December to January. The percentage occurrence of receptacles increased from 7 to 43% from February to May (Fig. 5). No reproductive branches were observed from June until November. *Sargassum siliquosum*, on the other hand, had reproductive branches throughout the study period but appeared to attain full maturity (with a marked increase in the number of receptacles) from September to December. A decline was noted in the following month with the degeneration of the population caused by decay of this species.

Discussion

In the tropical region where marked seasonal changes in temperature are absent, seasonal changes in algal population are influenced more by local physico-chemical conditions. Growth of *Sargassum* spp. in the Philippines is seasonal with both perennial and annual species (Trono 1992). The life cycle of *S. polycystum* appeared to be perennial with an absence of holdfasts having more than one stipe. *S. siliquosum* on the other hand is of the annual type with multi-stiped holdfasts observed throughout the study period. *Sargassum siliquosum* populations formed an almost close canopy during periods of maximum growth from October to December. The subtidal population of *S. siliquosum* was found to have longer thalli and greater biomass production as compared to the intertidal population of *S. polycystum*. This vertical zonation pattern could be attributed to the duration of exposure of the population and to the changes in temperature, light intensity, tide and water movement, producing indirect physiological responses from the plants. In the intertidal area, the extremes of environmental factors have resulted in the plant's diminished growth. Exposure to violent wave action during the monsoon period (August/September to November) also affected plant growth by mechanical tearing of the thalli and by reduced water transparency caused by the suspension of the bottom sediments. De Paula and Oliveira (1982) observed the same pattern in an *S. cymosum* C. Agardh population in Sao Paulo, Brazil in which exposure to wave action resulted to the smaller and shorter size of the plants in the rocky intertidal area. The persistence of *S. polycystum* year-round in the intertidal zone and its absence from the subtidal portion needs further investigation.

Growth of the subtidal population of *S. siliquosum* continues throughout the year until it undergoes normal decline. However, seasonal monsoonal pattern can decrease bio-

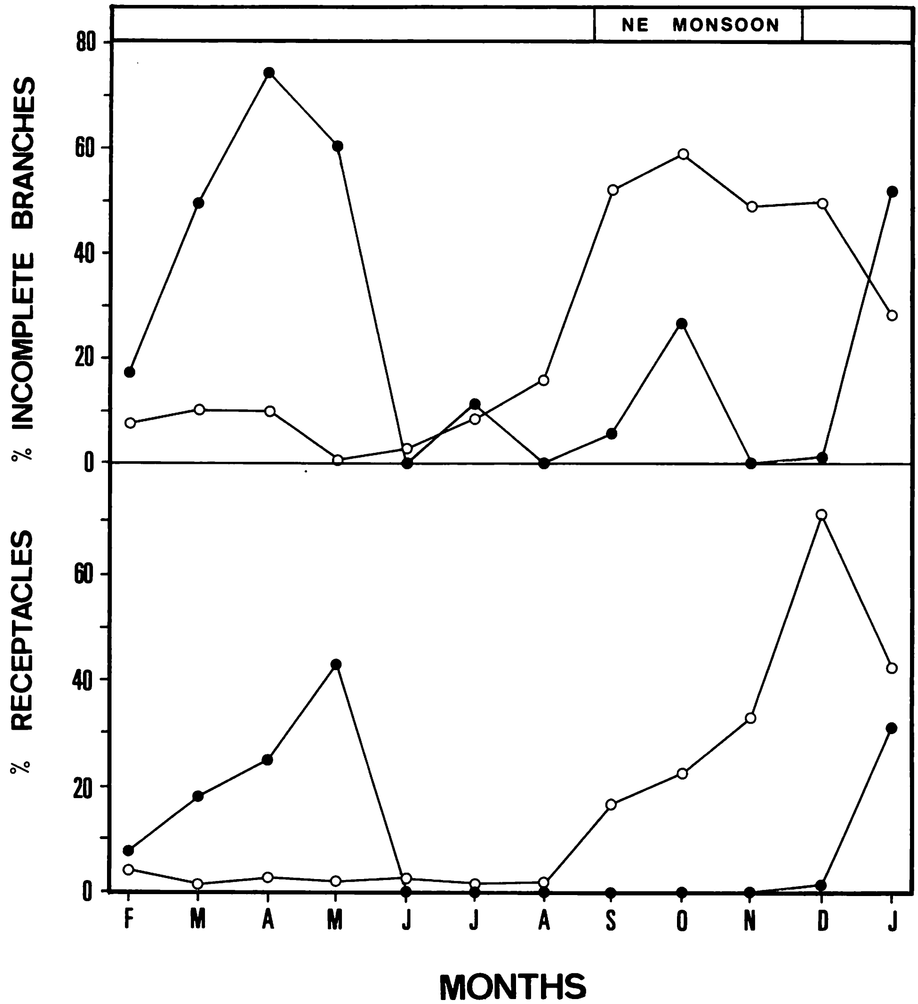

Fig. 5. Monthly variation in percentage receptacle occurrence and thallus condition (based on incomplete branches). *S. polycystum* (●), *S. siliquosum* (○). Note period of monsoon occurrence.

mass prematurely as shown by the high frequency of incomplete plants during this period, decreasing standing crop of all three subtidal quadrats in November. A slack in monsoon-generated waves, however, may allow an increase of biomass production in the subtidal area in December. Peak growth in terms of length and weight of the primary lateral branches in a previous study of this species likewise occurred at this period (Largo and Ohno 1992).

Standing crop increases in both species were due to the appearance of receptacle-bearing lateral branches as the plants became fertile (see also Largo and Ohno 1992). *S. polycystum* and *S. siliquosum* do not mature at the same period, with an early maturation period in *S. polycystum* (March-May) than *S. siliquosum* (September-December; see also Largo and Ohno 1992). There was no clear pattern of primary lateral length and standing crop variation in *S. polycystum* on a monthly basis because of the variability of the conditions in the intertidal zone which, to some extent, depends on the duration of exposure and the time of the day at which low tides occur. The maximum tidal range in the study area, based on the local tide table, was about 2 m during high water of spring tides (June). In the subtidal zone, the pattern of monthly changes in length was more regular as compared to the monthly changes in standing crop. Doty (1971, as cited by de Wreede 1976) in his study on Hawaiian *Sargassum*, attributed the apparently random fluctuation in standing crop to the similarly random occurrence of storm waves. Continued increase in the length of the primary lateral branches in *S. siliquosum* population in December (see also Largo and Ohno 1992) was offsetted by the cropping effect of the monsoon-generated waves, although growth of a large number of reproductive branches and of second- and third-order lateral branches compensated for this loss, enabling the plants to attain high standing crop values during this period.

The influence of temperature variation on *Sargassum* population fluctuation has been studied in Hawaii by De Wreede (1976) who observed that peaks of *Sargassum* standing crop, thallus height and fertility all occurred at a time of lower seawater temperature. In this study, highest receptacle occurrence observed for *S. polycystum* also coincided with months with lower temperatures. Largo and Ohno (1992) observed that *Sargassum* in this area develops longer primary lateral branches at the time when water temperature was at 27°C. De Wreede (1976) also observed the same pattern in Hawaii. Longer thalli in *Sargassum* in the subtropical waters likewise occurred at period of warm water temperature approximating that of the tropical waters (Kimura *et al.* 1987).

The biomass of *Sargassum* in the study area, appears to be low as compared to other coastal areas in the Philippines. For instance, *S. polycystum* in Bohol and Palawan areas has a mean standing crop of 4.30 and 2.69 kg wet wt.m^{-2}, respectively (Ohno *et al.* 1987; Ohno *et al.* 1989), compared to the study area with a range of 0.49 to 2.16 kg wet wt.m^{-2}. However, this may not represent the true picture as these studies were done on different periods. *S. siliquosum*, on the other hand, has a biomass range of 0.42 to 5.90 kg wet wt.m^{-2} which is higher than values reported from a nearby area in Mactan Is., Cebu (2.69 kg wet wt.m^{-2} as reported in Ohno *et al.* 1987).

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Danilo B. Largo・大野正夫・Alan T. Critchley:フィリピン，セブ島 Liloan 沿岸の *Sargassum polycystum* と *S. siliquosum* の成長と生殖の季節的変化

セブ島 Liloan 沿岸にはホンダワラ属の *S. polycystum* と *S. siliquosum* の群落がみられる。この 2 種は成育層が異なり *S. polycystum* は潮間帯に，*S. siliquosum* は潮下帯にみられる。*S. polycystum* の最大主枝長は 26.71 cm，現存量は 3.07 kg wet.m^{-2} であり，*S. siliquosum* の最大主枝長は 54.53 cm，現存量は 6.61 kg wet m^{-2} であった。*S. polycystum* の主枝長と現存量は，*S. siliquosum* のそれらと比較して，通年低い値を示した。生殖器床の出現率は 2 種により季節的違いが見られたが，両種とも主枝長と現存両の季節的変化は，北東モンスーンの影響を強く受けていた。

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