Journal of Applied Phycology (2006) 18: 629–636
DOI: 10.1007/s10811-006-9071-5

Phenology of *Sargassum spp*. in Tung Ping Chau Marine Park, Hong Kong SAR, China

Put O. Ang, Jr.
Environmental Science Programme, Department of Biology, The Chinese University of Hong Kong, Shatin, N.T. Hong Kong SAR, China

e-mail: put-ang@cuhk.edu.hk

Key words: *Sargassum*, seaweeds, Hong Kong, phenology, growth, plant length, reproduction

Abstract

Eight species of the brown alga *Sargassum* have been recorded from Tung Ping Chau Marine Park in Hong Kong and the phenology of four of these was monitored from 1996 to 2000. All four species followed a typical growth cycle of *Sargassum* species reported elsewhere but with some annual variations. For *S. hemiphyllum*, the maximum mean (±SD) plant length, ranging from 38.5 ± 10.5 to 61.9 ± 19.9 cm, was recorded in January to March. The peak reproductive season was also mainly in February to March with up to 89% of the plants being reproductive. Some plants, however, remained reproductive until May. For. *S. henslowianum*, the maximum mean plant length, ranging from 45.5 ± 25.5 to 77 ± 24.8 cm, was recorded mainly in November to January. The peak reproductive season was in November to February with up to 100% of the plants being reproductive. For *S. siliquastrum*, the maximum mean plant length, ranging from 48.2 ± 29.9 to 63.4 ± 22.1 cm, was also recorded mainly in January. The reproductive plants were found mainly between late December and mid February with up to 98% of the plants being reproductive. For. *S. patens*, the maximum mean plant length ranging from 87.6 ± 62.4 to 118.7 ± 41.3 cm was recorded in January to March. Reproduction of this species was not monitored. Changes in water temperature over seasons were likely to be critical in affecting the phenological patterns of these species.

Introduction

Hong Kong is located on the southern coast of China. About 200 species of marine macrobenthic algae have been reported from this area (Ang, 2005). These algae are mainly distributed on the eastern shore and are characterized by both temperate as well as tropical species. Hong Kong algae were reported to exhibit a strong seasonality in their abundance (Hodgkiss, 1984). Most algae grow during the colder months from October to May, and disappear completely during the hot summer of June to September. This pattern is particularly true for the intertidal species. Information on subtidal algae, however, is very limited or almost non-existent. Until recently, there have been no detailed studies on the phenology of any algal populations within Hong Kong waters. This is partly because many of the areas where algal species are found are not readily accessible, and partly because the interest in algal studies has been limited.

On tropical and subtropical coasts exposed to strong or moderately strong waves, brown algae of the genus *Sargassum* are usually dominant in terms of algal cover and standing crop. The coast around Hong Kong is no exception. This study is an initial attempt to examine the phenology of *Sargassum* populations in Hong Kong water in greater detail, to contribute to our general understanding of the Hong Kong marine environment. Many of the coastal areas in Hong Kong where *Sargassum* spp. are dominant are currently threatened by marine pollution and coastal reclamation projects. An understanding of the dynamics of these algal species is essential in providing baseline information to assess environmental impacts caused by coastal developments.

Most studies undertaken elsewhere have indicated that *Sargassum* populations have a seasonal cycle of

growth, reproduction, senescence and die-back (e.g. De Wreede, 1976; Ang, 1985; Largo & Ohno, 1992; Kendrick 1993). The timing of die-back, however, appears to vary according to species and locality. Tide has been suggested to be a critical factor in structuring the phenological patterns of two *Sargassum* populations from the Philippines (Ang, 1985). *Sargassum* died back at the time when lowest low tide of the year exposed the plants for a prolonged period. It is, however, not clear if the influence of tide plays a similar critical role in other *Sargassum* populations. Many *Sargassum* populations are found in the subtidal, i.e. they are never exposed to air. Questions remain as to whether these plants also exhibit seasonal die-back, just like their intertidal counterparts.

Materials and methods

This study was carried out in Long Lok Shui, on the western side of the island of Tung Ping Chau (114°26′E, 22°33′N), on the northeastern part of New Territories, Hong Kong (Figure 1). This island and the surrounding sea area are now a marine park. The study site is characterized by the presence of outcrops of sedimentary rocks, mainly shale, to which the marine algae are attached. Most of the algae are confined within the intertidal and shallow subtidal areas, extending to a depth of 10 m below Chart Datum. At least eight species of *Sargassum*, *S. angustifolium* (Turn.) Ag., *S. enerve* Ag., *S. fusiforme* (Harv.) Setch., *S. glaucescens* J. Ag., *S. hemiphyllum* (Turn.) Ag., *S. henslowianum* C. Ag., *S. patens* Ag. and *S. siliquastrum* (Turn.) Ag., may be found in the low intertidal to shallow subtidal, with the latter four species, *S. hemiphyllum, S. henslowianum, S. patens* and *S. siliquastrum,* being the most dominant.

The phenology of these four dominant *Sargassum* species was monitored. Biweekly to monthly visits to the site were conducted over the period of three and a half years, from November 1996 to June 2000, to study *S. hemiphyllum, S. henslowianum* and *S. siliquastrum* and from November 1997 to May 2000 to study *S. patens*. On each visit, 100 individuals of each of these four *Sargassum* species were haphazardly selected and measured. The maximum length was measured as the distance between the holdfast and the longest branch. For each individual, the presence or absence of reproductive structures (receptacles) was also noted. The peak reproductive season was considered to be the time when the highest percentage of the plants bore receptacles. All measurements were done *in situ* by snorkelling or SCUBA diving.

Results

Over the three and a half year sampling period, *S. hemiphyllum* attained a maximum mean plant length (± SD), ranging from 38.5 ± 10.5 to 61.9 ± 19.9 cm, mainly in January to March (Figure 2A). The longest mean plant length was recorded in February 28 1999 and the longest plant recorded at this same time was 109 cm in length. The peak reproductive season was recorded also mainly in February to March with up to 89% of the plants being reproductive (Figure 2B). Some individuals may remain reproductive until May. The plants died back very quickly from March to May after releasing their gametes. New laterals started to emerge from the holdfast and grew very slowly from May to September, before starting their rapid growth phase in November. There is evidence to indicate that some individuals survived only for one year.

Based on monitoring of tagged individuals, *Sargassum henslowianum* was shown to be a perennial species (Ang, unpublished). Individuals of this species attained their maximum mean plant length (± SD), ranging from 45.5 ± 25.5 to 78.36 ± 27.63 cm, mainly in November to January (Figure 3A). The longest mean plant length was recorded in Nov 28 1998 with the longest plant of 169.9 cm also recorded then. The peak reproductive season was in November to February, with up to 100% of the plants being reproductive (Figure 3B). Die-back occurred from February to April, and new laterals from the holdfast grew slowly from May to September. Rapid growth took place from September onward. There were some annual variations in the time the plants attained their maximum size and their peak reproductive period. Individuals of this species attained their maximum length in January 1997 and January 1998, whereas they attained their maximum length much earlier in November 1998 and November 1999 in the subsequent annual growth cycles. The rapid growth period in both 1998 and 1999 appeared to be shorter by two months than that in 1997 (and presumably also in 1996). This variation was not obvious in other species. The reproductive period was also earlier and longer in 1999. There were apparently two peaks of reproduction and some plants were found to be reproductive in May to September 1999. There was also a shift in the onset of reproductive period with some plants becoming reproductive earlier in October

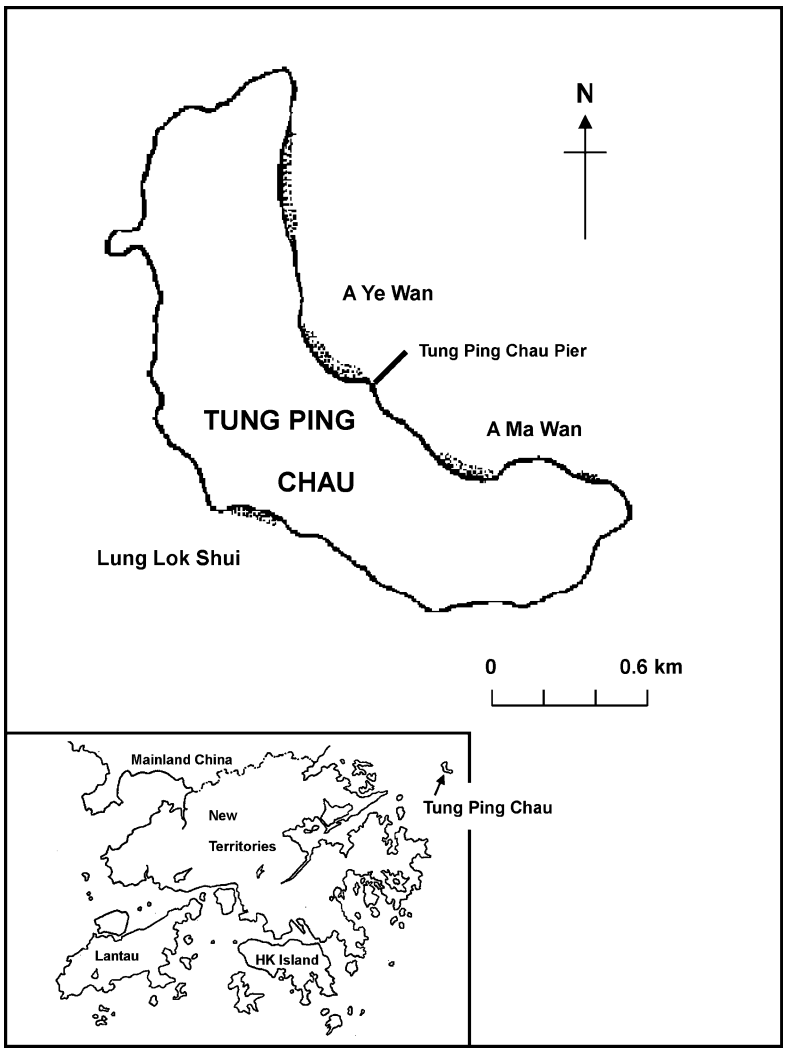

Figure 1. Map of Tung Ping Chau Marine Park showing the location of the study site, Lung Lok Shui. Insert: map of Hong Kong showing the location of Tung Ping Chau.

1998 and 1999 as compared with December in 1996 and late November in 1997.

Sargassum siliquastrum is also a perennial species (Chan, 2002). Individuals of this species attained their maximum mean plant length (± SD), ranging from 48.2 ± 29.9 to 63.4 ± 22.1 cm, mainly in January (Figure 4A). The longest mean plant length was recorded in January 4 1998 and the longest plant measured was 114.2 cm in length. There was a second, but much smaller peak of mean plant length recorded in June 1997, but this was not obvious in July 1998 nor was it observed in 1999. The reproductive plants were found mainly between late December and mid February with up to 98% of the plants being reproductive (Figure 4B). The onset of the reproductive period was apparently earlier in 1999. A few individuals (<2%) were found to have their receptacles in May 2000. This appears to be an exception rather than the rule as no reproductive plants were observed within the same period in the previous three years.

For *Sargassum patens*, also a perennial species, the maximum mean plant length (± SD), ranging from 87.6 ± 62.4 to 118.7 ± 41.3 cm, was recorded in January to March (Figure 5). Individuals of this species were the longest among the four species of *Sargassum* examined. The longest individual was 204 cm in length, recorded on March 29 1998. The longest mean plant length (±SD) was also recorded on March 29 1998.

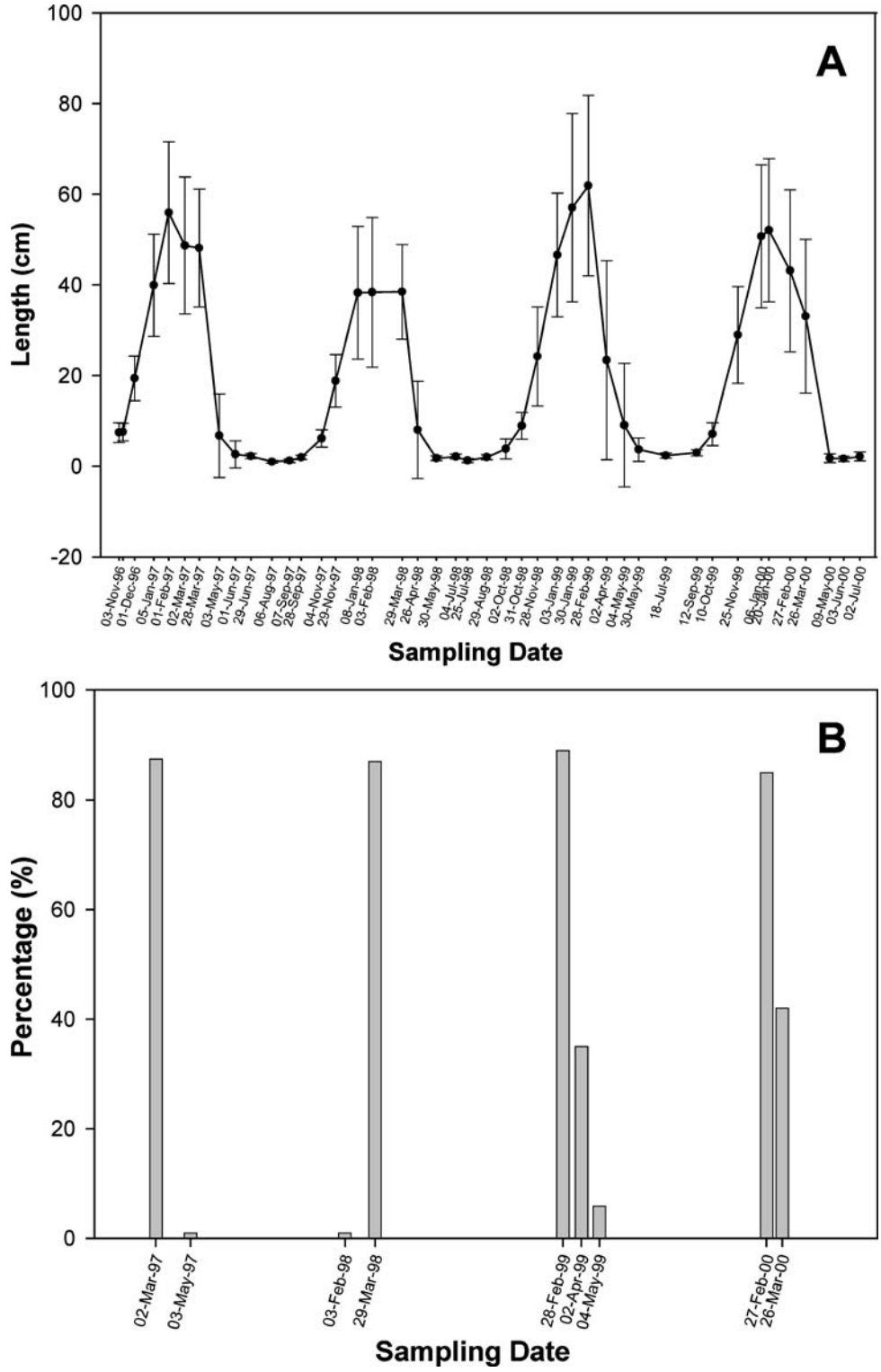

Figure 2. (A) Mean length (±SD) of 100 individuals in the *Sargassum hemiphyllum* population at different sampling dates over the study period. (B) Percentage of individuals in the population of *Sargassum hemiphyllum* that became reproductive at different times.

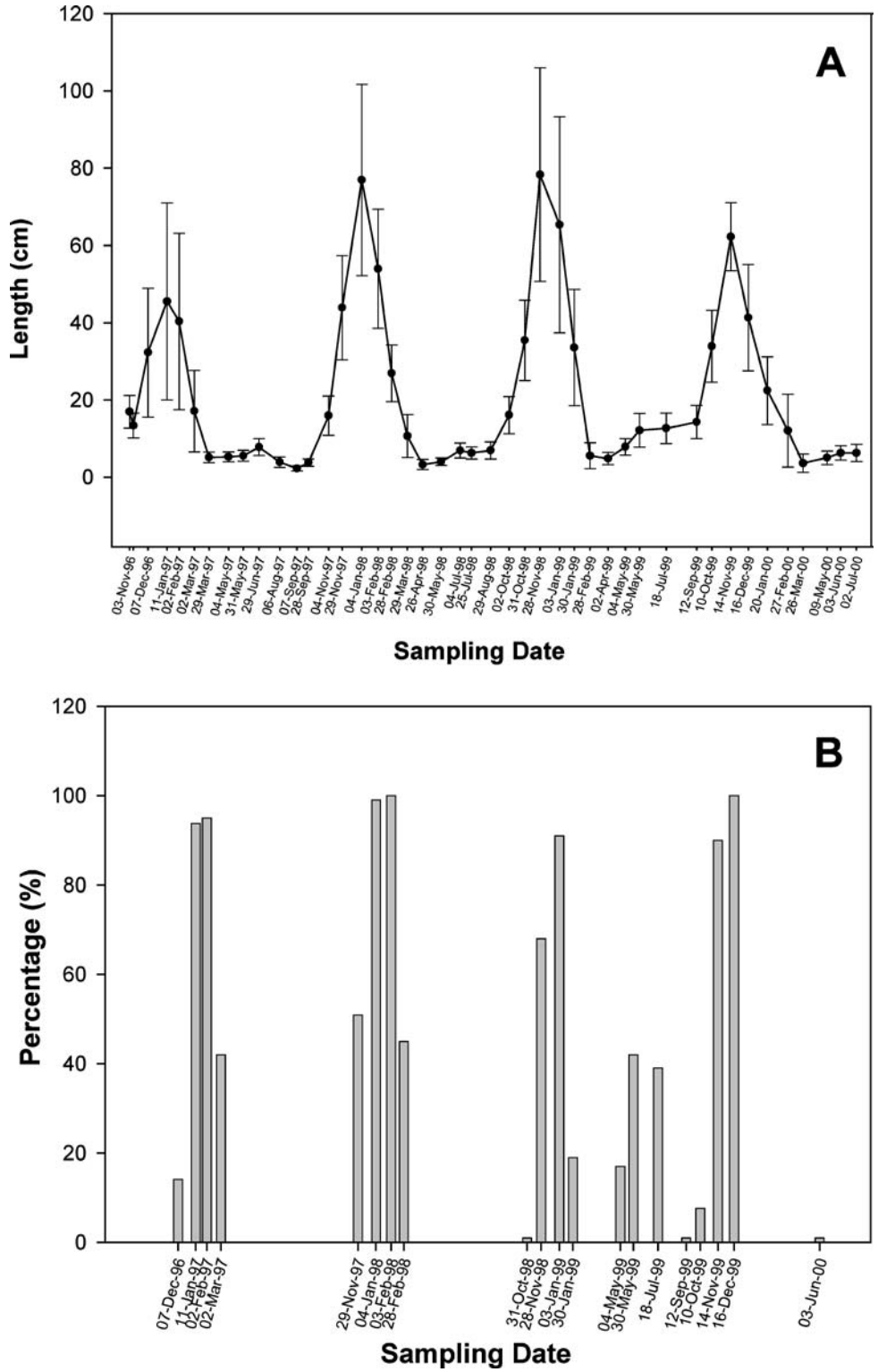

Figure 3. (A) Mean length (±SD) of 100 individuals in the *Sargassum henslowianum* population at different sampling dates over the study period. (B) Percentage of individuals in the population of *Sargassum henslowianum* that became reproductive at different times.

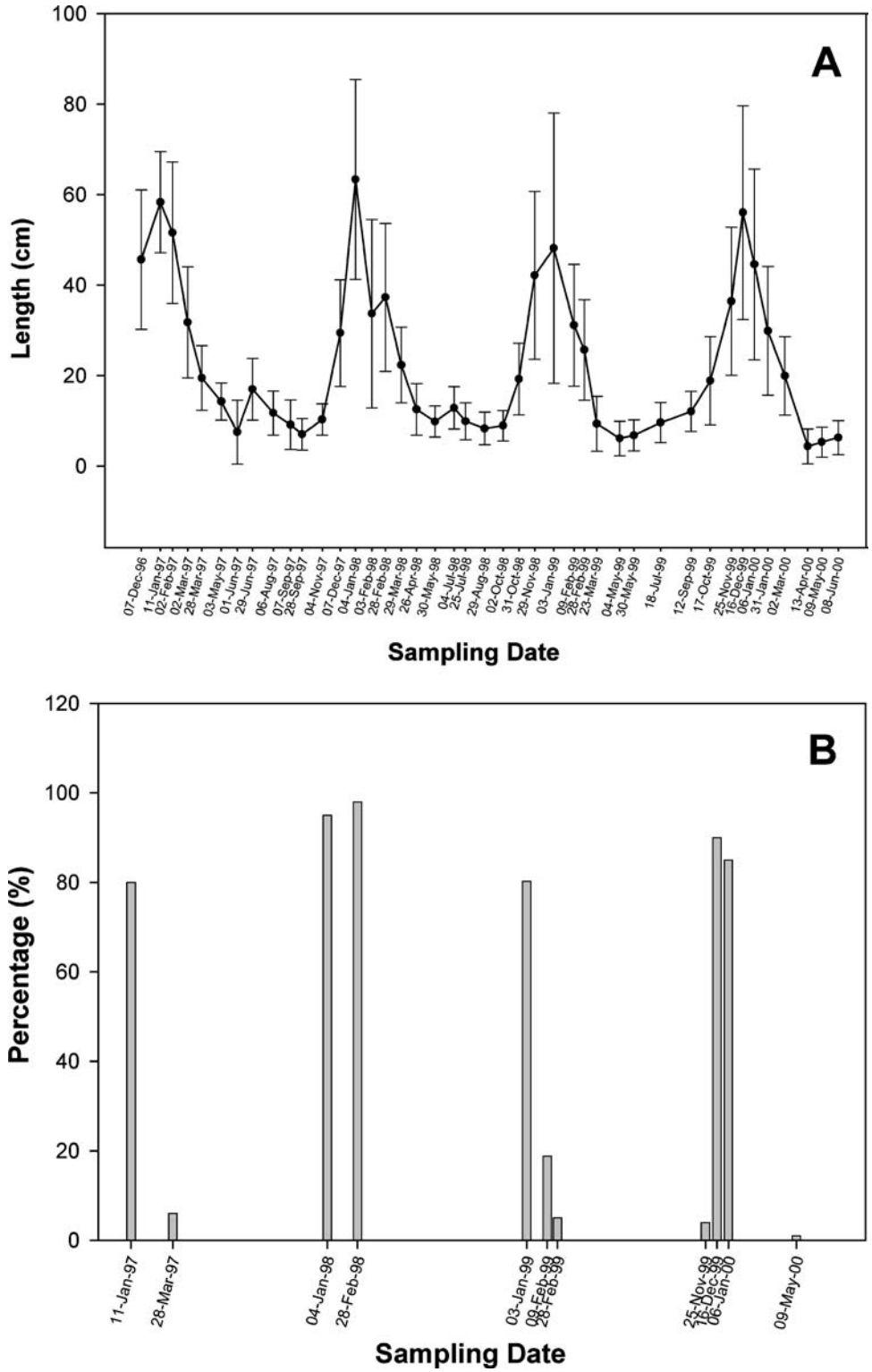

Figure 4. (A) Mean length (±SD) of 100 individuals in the *Sargassum siliquastrum* population at different sampling dates over the study period. (B) Percentage of individuals in the population of *Sargassum siliquastrum* that became reproductive at different times.

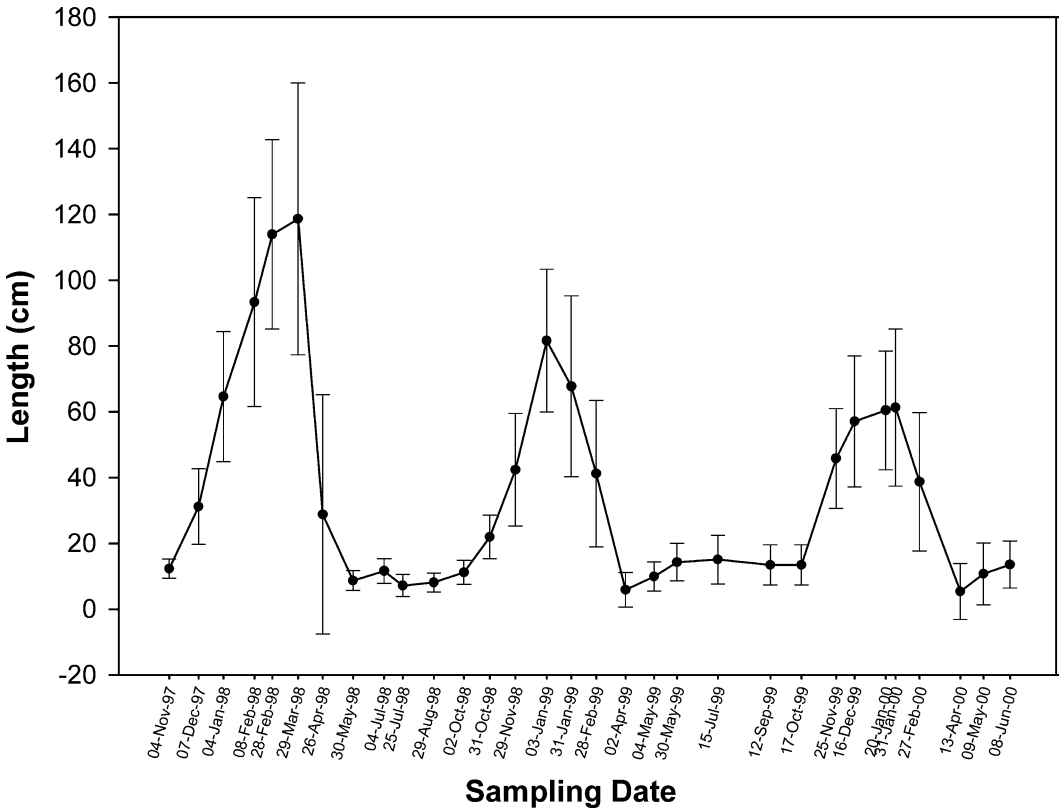

Figure 5. Mean length (±SD) of 100 individuals in the *Sargassum patens* population at different sampling dates over the study period.

Reproduction of this species was not monitored but it was likely to be around January to March as die-back commenced rapidly in March to April in 1998 or even earlier in 1999 and 2000. Plants were slow in growth from May to October and, rapid growth took place from October to December. There was an apparent drop in the size of the plants from 1998 to 2000. Around 70% of the individuals measured in March 1998 were longer than 1 m, while only 5% of the individuals were more than 1 m in length in January 2000. The longest plant measured in January 2000 was only 132.2 cm in length.

Discussion

All four species examined in this study followed a typical growth cycle of *Sargassum* species as reported elsewhere (e.g. McCourt, 1984; Ang, 1985; Huang et al., 1990; Largo & Ohno, 1992; Kendrick, 1993; Wong & Phang, 2004). This cycle is characterized by the presence of a slow growth phase, a rapid growth phase, and a reproductive phase that is followed by senescence and die back. Some annual variations, however, were observed between and within species. This is especially so with respect to the timing of rapid growth, the time when maximum plant size is attained and the timing and duration of reproductive period.

Sargassum hemiphyllum exhibited rapid growth and attained maximum size and reproduction later in the season than the other three species. These differences in growth and reproductive seasonality may be related to its spatial location along the tidal gradient. *Sargassum hemiphyllum* is present mainly in the lower intertidal and shallow subtidal zones. It occurs at the highest tide level of the *Sargassum* species examined in this study. *Sargassum henslowianum* is found mainly in the shallow subtidal, followed by *S. siliquastrum* and *S. patens* which are found in slightly deeper waters than *S. henslowianum.* The distribution range of *S. siliquastrum* extends to 10 m below Chart Datum, but the phenological patterns observed here are mainly those of individuals found in less than 3 m depth.

The tidal cycle in Hong Kong is mainly mixed semidiurnal. Daytime lowest low tide starts to occur

in spring and is the lowest in July. *Sargassum hemiphyllum* could be exposed at extreme low tide in midspring to summer but the other three species are true subtidal species and are not exposed to air even during the lowest tide in July. Die-back of *S. hemiphyllum* plants in March to May could be correlated with their emergence in the spring low tide. However, the other three subtidal *Sargassum* species started to die back before March, or even earlier. Changes in tidal level are therefore unlikely to have significant effect on the phenological patterns observed for these species.

Notwithstanding some inter-annual variations, all the *Sargassum* species examined in this study grew slowest during summer. All grew fast during autumn, when seawater temperature started to become colder. Maximum plant lengths were attained during the coldest months (January to March), when the majority of the individuals also became reproductive. De Wreede (1976) suggested that various species of *Sargassum* may be divided into cold water species or warm water species depending on when their peak growth and reproductive periods occur. He further suggested that the survival of the germlings, i.e., at what temperature range or season would they survive best, is critical in determining the reproductive seasonality of the populations (DeWreede, 1978). Some of the *Sargassum* species found in HongKong, e.g. *S. siliquastrum* and *S. patens,* are also found in temperate regions such as Japan and Korea. In Japan, *S. patens* attains its maximum sizes and becomes reproductive in late spring (Taniguchi & Yamada, 1978). Hong Kong winter water temperatures, at 14 to 16 °C, are comparable to the spring or summer temperature in many temperate regions. The shift in peak growth and reproductive periods from winter in subtropical areas like Hong Kong to spring and summer in temperate regions like Japan suggests temperature to be one of the most critical factors in affecting the phenological patterns of *Sargassum* spp. observed in Hong Kong and elsewhere.

The present study provides one of the longest terms (three and a half years) of phenological data on *Sargassum* ever collected. Although some inter-annual variations are observed, in general the phenological pattern among species is consistent over the years. Differences at the micro-level, e.g. between same month in different years, need further evaluation. Further assessment will be carried out to evaluate differences in phenological patterns observed among *Sargassum* species with respect to temporal changes in the environmental parameters as well as spatial changes along a latitudinal gradient.

Acknowledgements

The author wishes to acknowledge with appreciation the help provided by Tso Ka Yip, Kong Sau Lai, Chan Wai Yi and Tam Tze Wai in the field. Comments from two anonymous reviewers were most helpful. This project was supported by a RGC Earmarked Research Grant.

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