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Seasonality of standing crop of a *Sargassum* (Fucales, Phaeophyta) bed in Bolinao, Pangasinan, Philippines

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Abstract

The seasonality of standing crop of a *Sargassum* bed was investigated by conducting monthly sampling from February 1988 to July 1989. Environmental parameters of water movement, salinity, number of daytime minus tides, and water temperature were also measured. An intra-annual pattern of variation in standing crop of *Sargassum crassifolium*, *S. cristaefolium*, *S. oligocystum*, and *S. polycystum* was observed. Standing crop was generally lowest in February, March, April, or May, and highest in November through January. *Sargassum* accounted for about 35 to 85% of the monthly algal standing crop of the bed, and the observed variation in overall standing crop of the bed generally reflected the standing crop of *Sargassum*. The seasonality of the standing crops of the associated algal divisions also followed an annual cycle, but their maximum and minimum standing crops did not coincide with those of *Sargassum*. Individually, as well as collectively, the standing crops of the *Sargassum* spp. were poorly correlated with the environmental factors observed.

Introduction

The increasing commercial harvesting of *Sargassum* as raw material in the manufacture of seaweed meal is reflected in the significant upward trend in the export of this product to other countries during the last few years. In 1987, some 4,188 metric tonnes of *Sargassum* meal worth P10 million (about US$476,000) were exported (Bureau of Fisheries & Aquatic Resources Statistics). However, no data on the amount of *Sargassum* utilized locally in the manufacture of animal feeds are available. The gathering of *Sargassum* currently is concentrated in central Visayas and northern Mindanao, where fishermen claim that the unregulated gathering of *Sargassum* has resulted in the destruction of beds, which in turn has caused the decline of fish stocks in the area.

Herein, we report on one aspect of studies we are pursuing to gather basic information on the biology and phenology of *Sargassum* beds to serve as a basis for formulating a management scheme for the rational utilization of the resource.

Materials and methods

The study was conducted from February 1988 to July 1989. The site is located on Bolinao at the reef edge about 1.5 km north-northeast of the islet of Dewey on Santiago Island (Fig. 1). The *Sargassum* bed extends about 100 m landward from the reef crest and more than 200 m seaward.

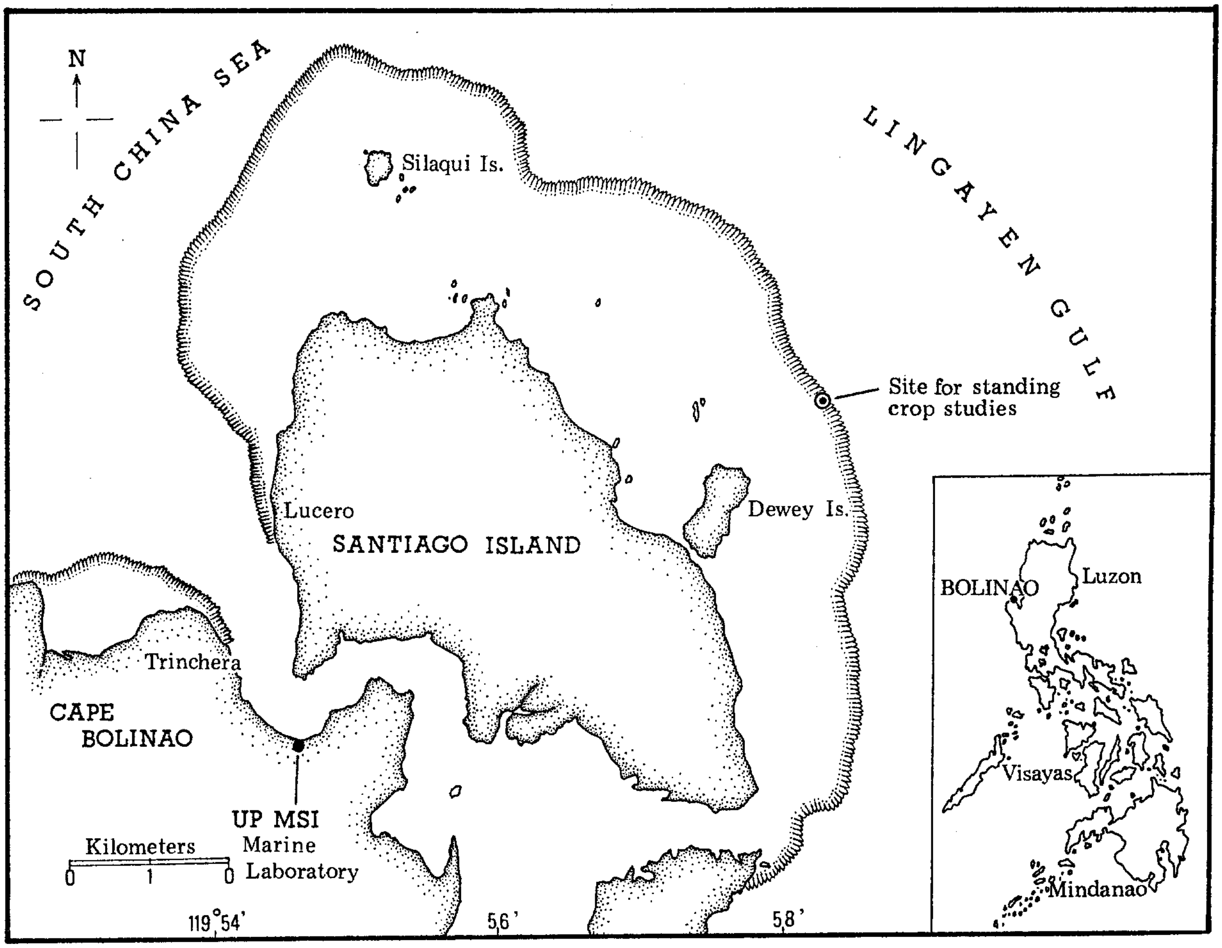

Fig. 1. Location of the study site.

The rocky-coral substratum, with coarse sand and coral rubble, gently slopes seaward. The seaward limit of the bed is located in about 8 to 11 m of water where *Dictyopteris* sp. co-dominates. The study site is exposed to strong waves and currents during the north-east (October to March) and south-west (June to September) monsoon seasons.

A permanent reference point (wooden post) was established at the reef crest. A calibrated line was tied to the post at the reference point and extended 100 m seaward across the shallow subtidal portion of the bed (wave-exposed). A second calibrated line was extended from the reference point 100 m landward across the intertidal portion of the bed (protected). The lines were permanent. A portion of the intertidal bed is exposed during extreme low tides, but is constantly wetted by waves.

A pair of modified belt transects positioned parallel to the two sides of the calibrated lines at the intertidal and subtidal portions of the bed were sampled using 0.25 m^2 metal quadrats. The metal quadrats were randomly dropped at 10-m intervals along the belt transects using the lines as guide. A total of 42 biomass samples were collected monthly. All algae inside the quadrat were collected and sorted, and the wet weights of all the species in the samples were recorded. The spatial and temporal distributions of the *Sargassum* spp. and associated species were analyzed using the data on biomass. These were correlated, using

Correlation Analysis (a subprogram of MICROSTAT*), with the monthly data on water movement (expressed in diffusion index factor, DF, values, Doty, 1971a), salinity, absolute number of daytime minus tides per month (i.e. the number of days in a month when lower low water is lower than the mean lower low water between 0600 and 1800 h), and water temperature. Daytime minus tides were taken into account because the occurrence of such tides often results in partial to complete exposure to air of the intertidal portion of the bed and exposure to very shallow water of the subtidal portion.

Results

Species composition and the contributions of the different plant groups to total biomass

The bed was generally dominated throughout the year by four species of *Sargassum*, *S. crassifolium* J. Agardh, *S. cristaefolium* C. Agardh, *S. oligocystum* Montagne, and *S. polycystum* C. Agardh (Fig. 2). Associated with *Sargassum* spp. were 73 species of macrobenthic algae: 30 Chlorophyta, 29 Rhodophyta, and 14 Phaeophyta, unidentified filamentous Cyanophyta, and three species of seagrasses. The latter were recorded only at the innermost limit of the bed.

Fig. 2 shows the monthly contributions of the different plant groups to total standing crop. Standing crop ranged from 510 to 2,129 g wet wt m^{-2} and averaged 1,192 g wet wt m^{-2}. The four *Sargassum* species accounted for about 61% of the average. During the months of November through January, *Sargassum* spp. attained an average of 1,508 g wet wt m^{-2}, or about 83% of total standing crop. The other phaeophytan species contributed 25%, Chlorophyta 6%, Rhodophyta 6% and seagrasses 1% to total standing crop. The Cyanophyta contributed an insignificant amount.

* MICROSTAT is a statistical software package, Copyright 1978-85 by Ecosoft, Inc.

Standing crop seasonality

For *Sargassum*, lowest standing crops were observed in March and April of 1988 and in March through May of 1989, and the highest from November 1988 through January 1989 (Fig. 2). Low standing crop was also observed in June when rough sea conditions caused by a passing typhoon removed a large amount of biomass. In October, only the inner protected portion of the bed was sampled due to very rough sea conditions also caused by a typhoon. Since *Sargassum* accounted for about 35% to 85% of the monthly total standing crop in the bed, the seasonal variation of the mean total algal standing crop merely reflected the seasonal variation of the mean *Sargassum* standing crop.

The seasonality of the standing crops of the individual *Sargassum* species followed the same general trend as that of total *Sargassum* standing crop, with lowest values in March, April, and/or May, gradually increasing in the succeeding months, attaining highest values in November and/or December. *Sargassum crassifolium* and *S. polycystum* attained highest standing crops in December (647 and 447 g wet wt m^{-2}, respectively), and *S. cristaefolium* and *S. oligocystum* in November (430 and 282 g wet wt m^{-2}, respectively).

The associated plant groups (Fig. 2) had high standing crops from February to May and low standing crops from June to January.

Spatial distribution of biomass

Fig. 3 shows the mean total, as well as the mean for *Sargassum* spp., of monthly standing crop for the inner and outer portions of the bed. On average, the mean total biomass recorded for the outer wave-exposed (subtidal) portion of the bed was slightly higher (1,261 g wet wt m^{-2}) than for the inner protected (intertidal) part of the bed (1,156 g wet wt m^{-2}). Standing crop in the outer portion was greater than in the inner portion during November through January, the months of highest standing crop in the bed. Approximately

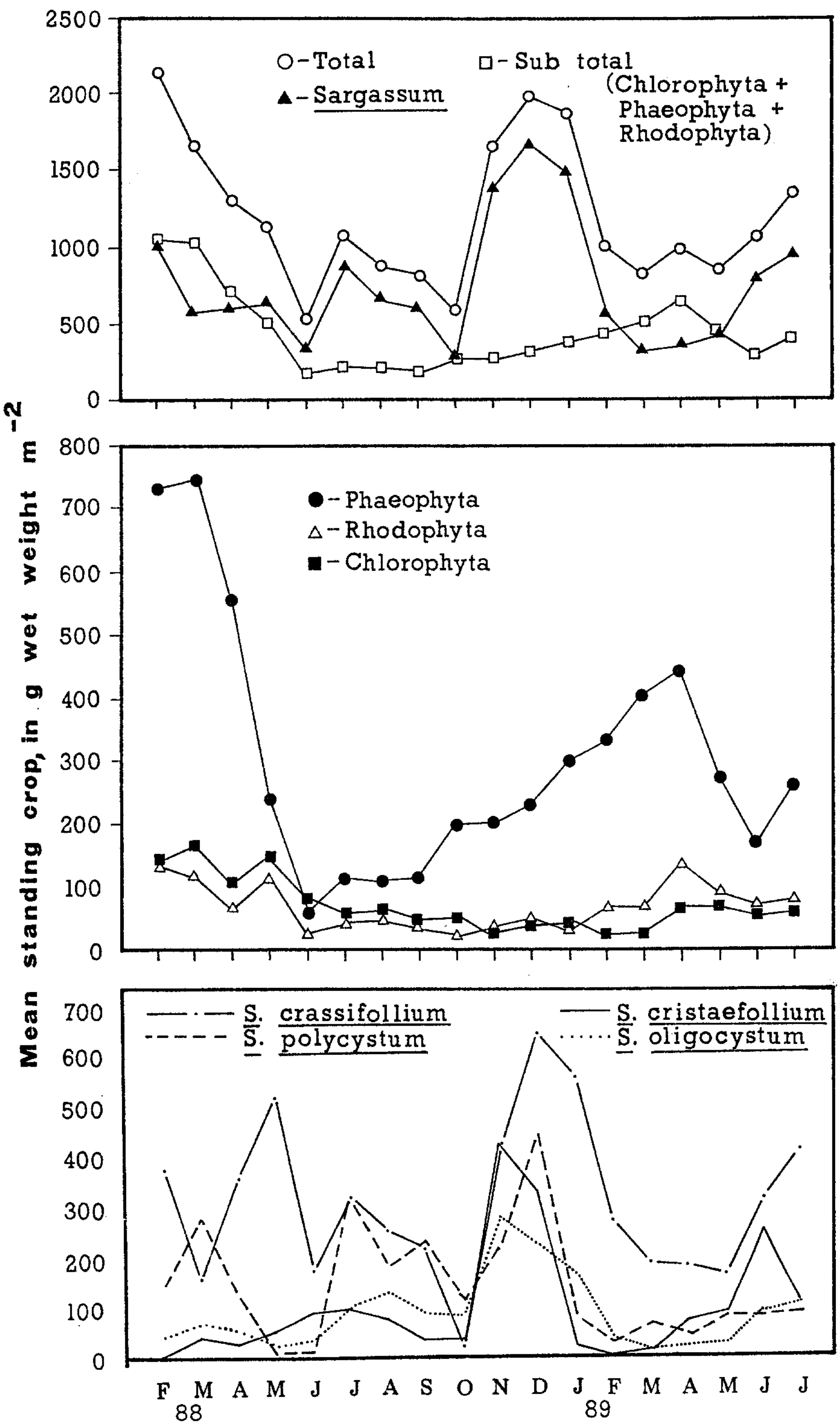

Fig. 2. Monthly mean standing crop of the different *Sargassum* species and algal divisions.

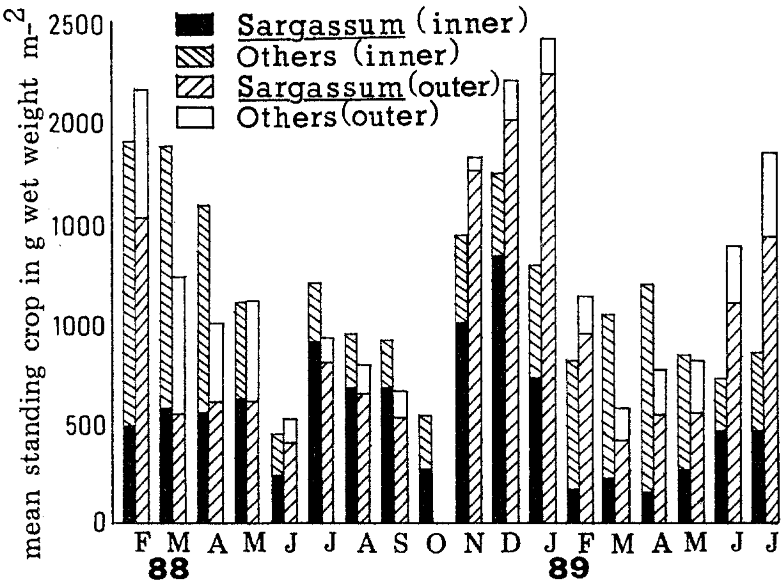

Fig. 3. Monthly mean standing crop of algal divisions in the inner and outer portions of the bed.

80% of the total biomass sampled in the subtidal portion during this period was contributed by *Sargassum* spp., particularly *S. crassifolium* and *S. cristaefolium*, which were more abundant in the outer portion of the bed. On the other hand, relatively higher standing crops were recorded in the inner portion of the bed from May to September in 1988. *Sargassum* standing crop in this portion of the bed consisted chiefly of *S. polycystum* and *S. oligocystum*.

The associated algal groups recorded generally higher standing crops in the inner portion of the bed than in the outer, wave-exposed portion. From February, 1988 to July, 1989, algal species other than *Sargassum* collectively contributed an average of about 594 g wet wt m^{-2} (50.4%) to the mean total standing crop in the inner portion of the bed and only 276 g wet wt m^{-2} (24.2%) in the outer portion.

Correlation with environmental factors

Individually, as well as collectively, *Sargassum* spp. showed insignificant correlations (Table 1) with the environmental factors (Fig. 4). Some of the more abundant associated species, however, showed high and significant correlations with some of the environmental factors. The specific correlations with environmental factors varied

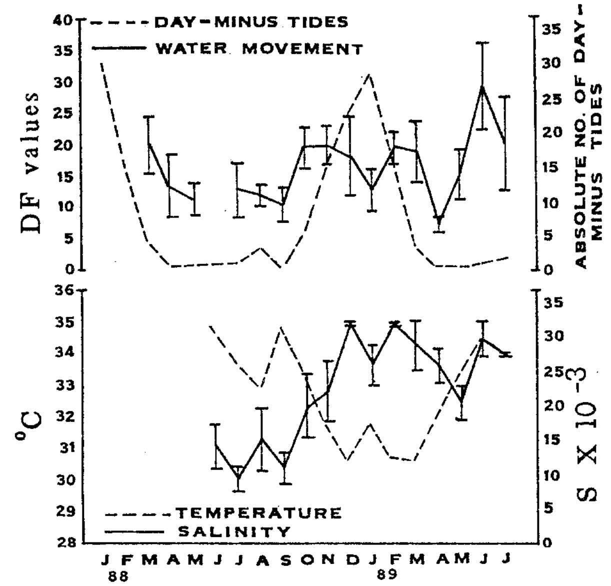

Fig. 4. Monthly data on water movement (± std. deviation), water temperature, absolute number of day minus tides, and salinity (± std. deviation).

Table 1. Correlation coefficients of standing crops of the most abundant species in each division and of whole divisions with physical parameters.

Species	Mean contribution to division's monthly standing crop, in %	Water temperature (°C)	Salinity	Daytime minus tides	Water movement (DF)
Chlorophyta					
Caulerpa racemosa (Forsskaal) J. Agardh	14.12	-0.50	0.45	-0.17	0.01
Halimeda macroloba Descaisne	6.32	0.37	-0.63*	0.46	-0.40
H. opuntia (L.) Lamouroux	46.20	0.68*	-0.81**	-0.34	-0.47
Valonia aegagropila C. Agardh	6.38	-0.33	0.24	0.24	0.00
Phaeophyta					
Dictyota cervicornis Kuetzing	9.13[a]	0.27	0.22	-0.53*	0.46
Hormophysa cuneiformis (J. F. Gmelin) Silva	30.38[a]	-0.20	0.29	0.67**	0.17
Padina spp.	8.37[a]	-0.36	0.51	-0.30	0.35
Sargassum crassifolium J. Agardh		-0.19	0.27	0.26	0.47
S. cristaefolium C. Agardh		0.20	-0.14	-0.26	0.27
S. oligocystum Montagne		0.23	-0.24	0.00	0.28
S. polycystum C. Agardh		-0.07	-0.14	0.27	0.17
Turbinaria conoides (J. Agardh) Kuetzing	29.24[a]	-0.75**	0.61*	0.69**	0.13
T. ornata (Turner) J. Agardh	15.41[a]	-0.55	0.32	0.18	0.30
Rhodophyta					
Actinotrichia fragilis (Forsskaal) Boergesen	12.23	-0.45	0.61*	-0.17	0.21
Amphiroa foliacea Lamouroux	27.01	-0.55	0.73**	0.35	0.58*
A. fragilissima (L.) Lamouroux	16.46	0.65*	-0.63*	-0.50	-0.15
Mastophora rosea (C. Agardh) Setchell	5.39	-0.24	0.42	-0.33	0.16
Chlorophyta	5.68	0.32	-0.22	0.04	-0.14
Phaeophyta (excluding *Sargassum*)	25.34	-0.75**	0.87**	0.59**	0.47
Sargassum	62.36	-0.04	0.08	0.34	0.43
Rhodophyta	5.55	-0.41	0.60*	0.23	0.32
Total (incl. sea grasses)	100.00	-0.24	0.33	0.59**	0.60*

* $p < 0.05$.
** $p < 0.01$.
[a] *Sargassum* excluded.

even within divisions. *Halimeda opuntia* (L.) Lamouroux and *H. macroloba* Decaisne, the most abundant chlorophytes, showed significant correlations with temperature and salinity, respectively, whereas the less abundant *Caulerpa racemosa* (Forsskaal) J. Agardh and *Valonia aegagropila* C. Agardh did not show significant correlations with any environmental factors. However, chlorophytes as a whole were not significantly correlated with any of the environmental factors. *Dictyota cervicornis* Kuetzing and *Hormophysa cuneiformis* (J. F. Gmelin) Silva showed significant correlations with daytime minus tides, whereas *Turbinaria conoides* showed significant correlations with water temperature, daytime minus tides and salinity. The rest of the more abundant phaeophytes, including *Sargassum* spp., showed insignificant correlations. As a whole, however, Phaeophyta showed significant correlations with water temperature, salinity, and daytime minus tides. Rhodophyta showed a significant correlation only with salinity although *Amphiroa foliacea* and *A. fragilissima*, two of the more abundant rhodophytes, showed significant correlations with water movement and temperature, respectively, and with salinity. *Mastophora rosea* was insignificantly correlated with the environmental factors measured.

Discussion

In the present studies, temporal variation in the standing crop of the *Sargassum* bed follows an annual pattern if no unusually rough seas (such as ones generated by typhoons) occur. For *Sargassum*, the lowest standing crops were observed in February, March, and/or April, and the highest during November, December, and January. The occurrence of the maximum standing crop of *Sargassum* coincided with the occurrence of low temperatures, which normally prevail from November to January. This observation is in agreement with the observations of DeWreede (1976) and McCourt (1984) that tropical *Sargassum* tends to be most abundant during the cooler months of the year. After this period of maximum standing crop, a rather abrupt reduction follows, indicating *Sargassum* dieback. During January or February, *Sargassum* spp. undergo senescence, and growth from new recruits begins in March through May. The only exception seemed to be *S. polycystum*, which remained vegetative throughout the year by regenerating new shoots from persistent rhizoidal holdfasts. Data obtained during the same period showed that *Sargassum* spp., except *S. polycystum*, attained highest fertility during January or February, before the sudden reduction in standing crop.

The low standing crops observed in June and October of 1988 were believed to be due to the occurrence of unusually rough seas during these months. Had these seas not occurred, the trend in standing crop seasonality would have been approximately monomodal (i.e. with only one high point) for the year. The data gathered in 1989 appear to support this supposition. Storms, however, are acknowledged to significantly affect standing crop and could influence algal biomass more strongly than the seasonal factors such as light and temperature (de Ruyter van Steveninck & Breeman, 1987; Doty, 1971b). *Sargassum*, being large, frondose, and buoyant, is liable to get detached from the substratum or from its holdfast by unusually strong water motion. In the Philippines, the tropical cyclone season is from June through December (Parong *et al.*, 1985), and rough sea conditions were observed in the area during these months even when storms did not directly pass over the area. In no month, however, was there a complete disappearance of any *Sargassum* species, even *S. cristaefolium*, which was reported to completely disappear from reefs in Guam during certain months (Tsuda, 1972).

The temporal variation in the standing crop of the associated algal divisions followed a basic pattern, namely, attainment of highest standing biomass in the early part of the year, followed by a somewhat abrupt reduction, then followed by a generally gradual rise (e.g. non-*Sargassum* Phaeophyta and Rhodophyta) or fall (e.g. Chlorophyta). The pattern appears similar to that of *Sargassum* in being apparently annual, but generally lagged two to three months behind *Sargassum*.

The poor correlations between *Sargassum* standing crop and the environmental factors suggest that *Sargassum* standing crop is not simply related to the environmental factors considered in this study. Poor correlations were also observed between standing crops of other, non-*Sargassum* species and environmental factors. Poor correlations could be due to natural lack of straightforward relationships between particular species and environmental factors, interference between or among factors, interference by unpredictable events such as unusually strong water motion, or importance of factors other than those considered in this study, such as biological interactions. Trono & Saraya (1987) observed that the abundance of associated species is significantly influenced by the amount of cover provided by large dominant benthic macrophytes such as *Sargassum* spp. and *Hormophysa cuneiformis*. Antecedent effects (Doty, 1971b) could likewise affect correlations between standing crops and environmental factors. A correlation between the standing crop of a species and one or more environmental factors does not necessarily produce a correlation between the standing crop of the division to which it belongs and the same environmental factors.

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