

Studies on photosynthesis and respiration in some marine Macroalgae of the Goa coast

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ABSTRACT

Primary production and respiration rates were measured in 14 marine macroalgal species from the Goa coast. The highest production rate was observed in *HYPNEA MUSCIFORMIS* and the lowest in *LAURENCIA PAPILLOSA*. Net production rates in these 14 species varied from 0.56 to 2.10 g/m^2 of the algal surface area/day. Estimates based on the measured net production rates and standing stock of these algae from the Goa coast indicate an annual production of 726 tonnes of carbon.

INTRODUCTION

Productivity of an ecosystem depends upon the amount of organic matter produced by plants by photosynthesis. Odum (1953) has suggested that land, fresh water and marine habitats are equally productive. The light energy from the sun is initially fixed by photosynthetic plants as chemical energy into monosaccharides. The productivity of a given ecosystem is governed by the total effective solar energy incident on the area, the efficiency of plants in transforming this energy into organic compounds and the physical factors in the environment that affect the rate of photosynthesis (Dice, 1952).

Marine plants generally photosynthesise and respire in a manner similar to fresh water and terrestrial plants (Norris *et al.* 1955; Black *et al.* 1976; Burries *et al.* 1976). Work on photosynthesis and respiration of marine plants has been carried out since the beginning of the 20th Century (Buesa, 1977). However, there

are only very few productivity estimates available for marine macrophytes. Mann (1973) has summarized the available production data for frondose macrophytes and Littler (1973) reported the productivity of tropical crustose coralline algae. These reports suggest that reef and coastal algal communities rank among the highest primary producers. Productivity was related for the first time to the algal thallus by Littler and Murray (1974). Ryther (1963) suggested that the worldwide production of benthic seaweeds may approach 10% of that of phytoplankton.

Production estimates of macrophytes along the Indian coasts are scarce. The work of Qasim and Bhattathiri (1971) was mainly related to the primary production of the seagrasses, *Thalassia* and *Cymodocea* beds from Lakshadweep. Although extensive work on the productivity of marine phytoplankton has been done (Qasim and Sankaranarayana, 1970; Pant *et al.*, 1976, 1980; Qasim, 1977; Bhattathiri *et al.*, 1980; Bhattathiri and Devassy,

1980) no attempts have been made to estimate the primary productivity of the macrophytes of the Indian coast.

In the present investigation, 14 algal species from the Goa coast (India) have been used to study the rate of net photosynthesis and respiration. An attempt has been made to categorize the more productive algal species and to relate net production with the standing crop in the form of turnover rates of the marine algae of the Goa coast.

MATERIALS AND METHODS

Fourteen marine algal species (3 chlorophyta; 5 Phaeophyta and 6 Rhodophyta) were used for the experiment. The species were *Ulva fasciata* Delile, *Chaetomorpha media* (Ag.) Kutz., *Caulerpa sertularioides* (Gmel.) Howe, *Spatoglossum asperum* J. Ag., *Padina tetrastromatica* Hauck, *Dictyopteris australis* Sonder, *Sargassum* sp., *Stoechospermum marginatum* (Ag.) Kuetz., *Hypnea musciformis* (wulf.) Lamour, *Gelidiopsis variabilis* (Grev.) schmitz, *Laurencia papillosa* (Forsk.) Greville, *Acanthophora spicifera* (Vahl) Boergs., *Gracilaria corticata* J. Ag. and *Grateloupia lithophila* Boerg. These algae were collected from the intertidal areas of the Goa coast and brought to the laboratory in plastic buckets filled with seawater. They were then cleaned with seawater to remove adhering sand particles and other debris. Care was taken to separate epiphytes, if any, from the algal thalli. The algae were then acclimatized for 24 hours under laboratory conditions (temperature range from 28°C to 32°C and normal daylight).

Net primary production and respiration were determined by the light and dark bottle method. Two light and two dark (painted with black paint and then covered with black adhesive tape) bottles of 1000 ml capacity were used for each algal species. The experiments were carried out at Dona Paula jetty between 1030 hours to 1230 hours. Incident solar radiation data was obtained from the India Meteorological Department, sub-station at Goa.

Initial oxygen content was measured in duplicate before and after every set of bottles were filled. Two sets of light and dark bottles filled only with seawater and incubated in the same way as that of the bottles containing algae served as controls. Photosynthesis and respiration values of the macrophytes have been corrected for the oxygen changes in the control bottles.

Healthy algal fronds of known weight were selected from the whole thalli and transferred carefully into the bottles filled with seawater. These bottles were stoppered tightly and incubated *in situ* for two hours by suspending from a triangular wooden frame. A preliminary series of experiments were performed to determine the period of incubation and the weight of algae to be used for the actual experiments. It was found that two hours and about 0.2 g of algal material was sufficient to give a measurable oxygen variation in light and dark bottle.

At the end of the incubation period, water was siphoned from each bottle for duplicate oxygen determinations. Dissolved oxygen concentration was determined

by the Winkler method (Strickland and Parsons, 1968).

All oxygen values (ml/hr) were converted into carbon values (gC/1/hr) by multiplying by a factor of $\frac{0.375}{PQ}$ and the value of PQ was taken as 1.2 (Strickland, 1960). Further, these values were converted to gC/m² /hr from the measured area of the algal thallus.

Algae were then removed from the respective bottles and brought to the laboratory where they were dried on blotting paper and then traced on the graph paper. The surface area of the algal thallus was computed by integrating the number of squares of each trace.

The production budget for the entire Goa coast was calculated by using standing crop data from the coast line and the average net primary productivity of the fourteen algae studied. Daily net production rate was calculated from hourly rates by deducting 24 hours of respiration from 12 hours of gross production. Production estimates reported here also include respiration by bacteria present on the algal thallus.

Correlation coefficient analysis were made to determine the relationship between gross and net production and respiration. Species-wise, correlation co-efficient analysis were not possible due to lesser number of observations. Hence, groupwise analysis were carried out to see the relationship between the three parameters (gross production, net produc-

tion and respiration). The magnitude of relationship was worked out by regression lines and its significance was tested against standard error of estimates.

RESULTS AND DISCUSSION

In the beginning, data was collected for water temperature, salinity and solar radiation. The water temperature during the period (February - March, 1980) of experiments varied from 29.0°C to 30.0°C and salinity varied from 35.4‰ to 36.0‰. Solar radiation varied from 0.39 cal/cm²/min to 0.77 cal/cm²/min.

In Chlorophyta, net production varied from 0.56 g C/m²/day to 1.8 g C/m²/day. Highest net production was observed in *U. fasciata* while lowest was recorded in *C. sertularioides* (Fig. 1). The highest production in *U. fasciata* was probably due to their flat thallus which minimizes self shading and the larger size of the cells give relatively little internal self shading by non - photosynthetic wall components (Littler, 1980). Respiration varied from 0.05 g C/m²/day to 0.85 g C/m²/day. Respiration rate was found to be low in *U. fasciata* while the highest was observed in *C. media* and *C. sertularioides*. The high rate of respiration in these two species could be because the thalli used in the experiment might have had some reproductive cells which are responsible for high respiration as suggested by Littler and Arnold (1980). In this group it is seen that *U. fasciata* is the most productive species, followed by *C. media* and *C. sertularioides* (Fig. 1)

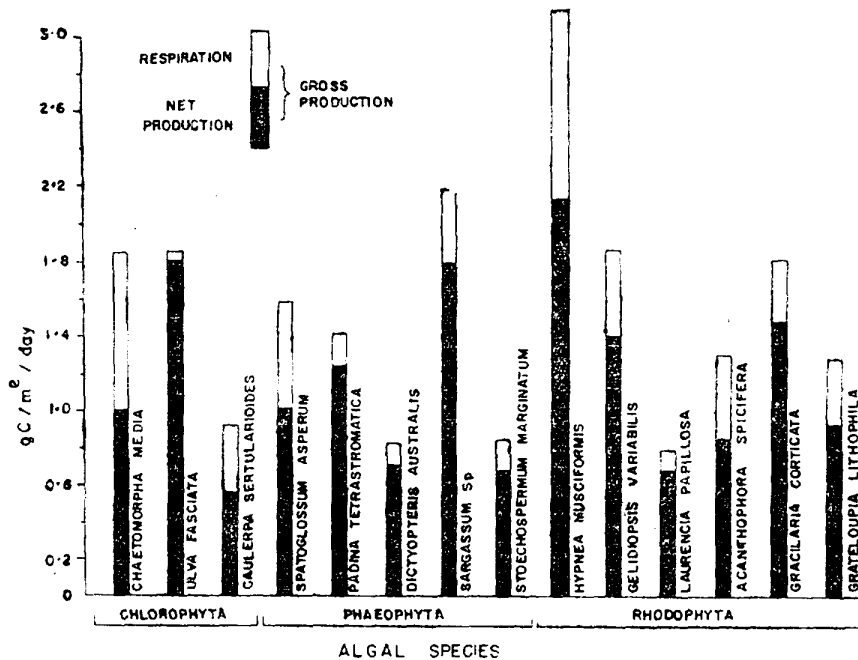


Fig. 1. ESTIMATED NET PRODUCTION, RESPIRATION AND GROSS PRODUCTION IN DIFFERENT SPECIES OF MARINE ALGAE

Table 1 Correlation coefficient between net production (NP), respiration (R) and gross production (GP).

<i>CHLOROPHYTA</i>			
	NP	R	GP
NP	1.00	-0.42	0.75*
R		1.00	0.29
GP			1.00
<i>PHAEOPHYTA</i>			
	NP	R	GP
NP	1.00	0.16	0.94*
R		1.00	0.48
GP			1.00
<i>RHODOPHYTA</i>			
	NP	R	GP
NP	1.00	0.80*	0.97*
R		1.00	0.92*
GP			1.00

* Significant at P 0.01

It can be seen from the Table 1 that relation between gross production and net production in this group is significant. On the other hand the relation between gross production and respiration is insignificant. Although the standard error of estimate for both the equations (regression lines) is of high magnitudes, the estimating equations are significant (Fig. 2). This indicates that the gross production is significantly related to net production as well as with that of respiration.

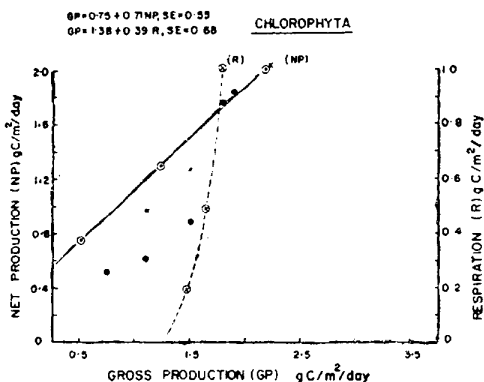


Fig. 2. SCATTER DIAGRAM SHOWING RELATIONSHIP BETWEEN NET PRODUCTION (NP), GROSS PRODUCTION (GP) AND RESPIRATION (R) IN CHLOROPHYTA SPECIES

In Phaeophyta, net production varied from 0.67 g C/m²/day to 1.79 g C/m²/day and respiration varied from 0.12 g C/m²/day. Highest production was recorded in *Sargassum* sp. while lowest was in *S. marginatum* (Fig. 1). Algal species from intertidal and subtidal areas have distinct metabolic differences which in turn affect the rate of photosynthesis and respirations. Subtidal species of *Spatoglossum*, *Padina* and *Sargassum* showed comparatively higher production (Fig. 1)

while species of *Dictyopteris* and *stoecho-permum*, even though subtidal in habitat, showed low production probably, because these species are collected from the intertidal rock pools for the experiment. Similar differences in the rate of production and respiration of subtidal and intertidal algae have been reported by Littler and Arnold (1980).

In this group gross production varied very closely with net production ($r = 0.94$). However, the correlation coefficient between respiration and gross production is statistically insignificant ($r = 0.48$). A variation in relationship between gross production as well as respiration was shown by regression coefficient. The regression coefficient in the case of net production is 1 while in respiration it is 1.4. These coefficients were significant on the basis of a 't' test in the case of net production but not in the case of respiration. This result is also evident from standard error estimates (Fig. 3)

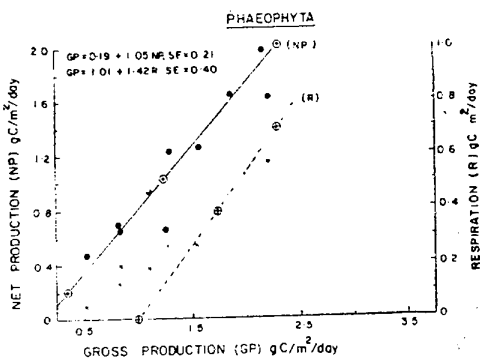


Fig. 3. SCATTER DIAGRAM SHOWING RELATIONSHIP BETWEEN NET PRODUCTION (NP), GROSS PRODUCTION (GP) AND RESPIRATION (R) IN PHAEOPHYTA SPECIES

In Rhodophyta, net production varied from 0.68 g C/m²/day to 2.1 g C/m²/day and respiration varied from 0.11 g C/m²/day (Fig. 1). Highest and lowest values of net production and respiration were observed in *H. musciformis* and *L. papillosa* respectively. Profusely branched *Hypnea* showed higher net production per unit weight than the less branched *Laurencia*, *Acanthophora* and *Grateloupia*. These algal species have proportionately more nonphotosynthetic structural tissue which reduces photosynthetic production per unit weight (Littler and Arnold, 1980).

The correlation coefficients between net production, respiration and gross production are all positive and significant at P 0.01.

The linear regression equation (Fig.4) obtained for estimating gross production from net production and respiration showed that gross production increases at a rate of

1.5 times the net production increases at a rate of 1.5 times the net production and 2.4 times respiration. The low values of standard error for both the equation showed that the linear regression obtained is significant (Fig. 4).

In the present investigation, *Dictyopteris*, *Spatoglossum* and *Gelidiopsis* (replicate samples) showed difference in production rate which was probably due to injury to the algal fronds in one of the samples. Hatcher (1977) has opined that injury to plants may lead to low production. According to Ragan and Jenson (1977) another probable explanation for low rate of production is that these algae have high concentrations of phenolic compounds in their tissue. When injured, they release the phenolic compounds into the surrounding water column which rapidly get oxidised to their corresponding quinones, thus affecting photosynthesis and respiration.

Littler and Murray (1974) showed that the highly productive species were *Gelidium pusillum* and *Ulva californica* from rocky intertidal community and reported that there is no relationship between the productivity of each algal species and the group of algae, as each group has species showing highest and lowest production rates. Similarly, in the present study, there are species in each group showing high and low productivity. Species of *Hypnea*, *Ulva* and *Sargassum* were the high productive species while *Laurencia*, *Caulerpa* and *Dictyopteris* were the low productive species of the Goa coast.

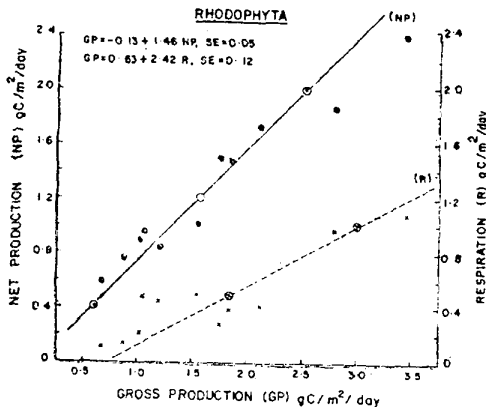


Fig. 4 SCATTER DIAGRAM SHOWING RELATIONSHIP BETWEEN NET PRODUCTION (NP), GROSS PRODUCTION (GP) AND RESPIRATION (R) IN RHODOPHYTA SPECIES

In the present study, net production values range from 0.56 g C/m²/day to 2.1 g C/m²/day which are in accordance with the values reported for five populations of crustose coralline algae (Littler, 1973) and for eighteen intertidal algal populations (Littler & Murray, 1974) (Table 2).

Table 2 Productivity estimates of populations and communities of various marine systems.

Sr. Nos.	Populations & Communities	Net Production gC/m ² /day	Reference
1.	Nine seaweed populations, California, U.S.A.	1.0 - 9.0	Blinks (1955), as recalculated in Pomeroy (1961).
2.	Caulerpa beds, Eastern Canary Islands	1.0	Johnston (1969)
3.	Marine macrophytic communities, Eastern Canary Islands	1.5 - 3.0	Johnston (1969)
4.	Thalassia and Cymodocea bed Kavaratti Ato., Laccadives	5.8	Qasim and Bhattathiri (1971)
5.	Seaweed zone St., Margaret's Bay, Nova Scotia, Canada	4.8	Mann (1972)
6.	Two reef communities, Eniwetok Atoll	1.6 - 7.2	Smith (1973)
7.	Five populations of crustose coralline algae, Waikiki reef, Hawaii	0.5 - 2.6	Littler (1973)
8.	Eighteen intertidal algal populations, San Celemnite Island U. S. A.	0.4 - 3.1	Littler and Murray (1974)

9.	45 species of macroalgae from four different environment in South Western N. America.	0.24 - 5.64	Littler (1980)
10.	Benthic algae from deep coral reef.	0.21 - 1.2	Vooren (1981)
11.	Fourteen intertidal algae of the Goa coast, India.	0.5 - 2.1	Present work.

On the basis of the daily mean production and standing crop in the respective localities, net production has been calculated. From these observations a yearly production estimate for the entire Goa coast

is 726.71 tonnes C/year. This estimate is lower than the estimated production for the species of *Fucus*, *Ascophyllum* and other rockweeds in temperate water (Mann and Chapman, 1975).

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