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Full Length Research Paper

Photosynthesis-irradiance curves of four marine macroalgae from Bolinao, Pangasinan and Calatagan, Batangas, Philippines

Floredel D. Dangan-Galon. [1,2], Richard V. Dumilag[2] and Edna Ganzon-Fortes[2]

[1] Marine Science Laboratory, Palawan State University, Puerto Princesa
[2] The Marine Science Institute, University of the Philippines- Diliman

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The study was conducted to determine the Photosynthesis -Irradiance or P-I curves of marine macroalgae namely *Ulva lactuca* Linnaeus, *Ganonema farinosum (*J. V. Lamouroux) K.C. Fan and Yung C. Wang, *Hydropuntia edulis* (S.G. Gmelin) P.C. Silva from Bolinao, Pangasinan and *Kappaphycus striatum* (F. Schmitz) Doty ex P.C. Silva from Calatagan, Batangas. Results indicated that among the given species, the *U. lactuca* obtained the highest P_{max} value at 61.8 mg O_2 g dw^{-1} hr^{-1} followed by *H. edulis* then *K. striatum* and lastly, the *G. farinosum* with the values of 15.2, 14.6 and 9.0 mg O_2 g dw^{-1} hr^{-1}, respectively. That sequence elucidated growth form- productivity relationship. The *U. lactuca*, being sheeted in form, had the highest oxygen production rate over the branching-form species, the *H. edulis, K. striatum*, and *G. farinosum.* However, the said relationship was not evident between species of different branching forms. The finely branched *G. farinosum* was expected to have had a higher photosynthetic rate than the coarsely branched *H. edulis* and *K. striatum* but the converse transpired. That suggested an equal consideration of rigidity and toughness of thalli to discriminate macroalgal species for growth form- productivity studies. The *G. farinosum* although finely branched is slightly calcified and that may have had a significant influence on the derived P_{max} sequence.

Key words: macroalgae, light-saturated, photosynthetic rate, growth-forms, P-I curves.

INTRODUCTION

Light affects photosynthesis in all autotrophic organisms including the marine macroalgae. It has been described that the photosynthetic rate is a hyperbolic function of light intensity (Lapointe *et al*., 1984) and the photosynthetic activities can be illustrated through the use of Photosynthesis- Irradiance (P-I) curve (Lalli and Parsons, 1993). P-I curve illustrates the relationship of light and the photosynthetic activity of the plant by measuring the amount of oxygen fixed per dry weight biomass per unit time (mg O_2 dwt^{-1} hr^{-1} or g C m^{-2} day^{-1}) at certain photon flux density or PFD (µmol photon m^{-2} s^{-1}). It has been used to quantify daily net photosynthetic efficiency of intertidal macrophytic community in California, USA (Littler and Murray, 1974; Littler and Littler, 1980), to evaluate acclimation responses of *Eucheuma isiforme* (C. Agardh) J. Agardh from Florida and *Kappaphycus alvarezii* (Doty) Doty and E*ucheuma. denticulatum* (N.L. Burman) Collins and Hervey from the Philippines (Dawes and Koch, 1988; Dawes, 1989; 1992), and to compare the photosynthetic responses of healthy and diseased *Kappaphycus alvarezii* (Ganzon-Fortes *et al*., 1993) , among others.

There are a number of factors that influence the P-I curve of macroalgae. This includes temperature, salinity, desiccation, water depth and movement, and amount of dissolved oxygen (Johnson *et al*., 1974; Mathieson and Dawes, 1973; Dawes *et al*., 1976; Downton *et al*., 1976; Lapointe *et al*., 1984; Stewart and Carpenter, 2003). However, photosynthetic rate is not exclusively driven by these factors (Luning, 1990) as it has been previously postulated that the morphology or growth forms correlate with photosynthetic efficiency of the plant (Littler and

*Corresponding author. E-mail: fddangan@yahoo.com.

Table 1. Measures of Photosynthesis-Irradiance (P-I) parameters of four benthic macroalgae from Bolinao Pangasinan and Calatagan, Batangas, Philippines.

Species	*U. lactuca*	*G. farinosum*	*H. edulis*	*K. striatum*
P_{max} (mg O g dw^{-1} h^{-1})	61.82	9.03	15.20	14.99
I_k (umol photons m^{-2} s^{-1})	138.12	79.55	89.91	34.25
I_s (umol photons m^{-2} s^{-1})	476.99	274.72	310.49	118.28
I_c (umol photons m^{-2} s^{-1})	6.64	20.34	10.34	5.48
Alpha (Light Harvesting Efficiency)	0.45	0.11	0.17	0.44
R_d (mg O g dw^{-1} h^{-1})	-2.97	-2.26	-1.74	-2.38

Murray, 1974; King and Schramm, 1976).

The study attempts to measure the photosynthetic activities of some selected macroalgae by illustrating their P-I curves. The results will be subsequently used to verify the growth-form hypothesis in Littler and Littler's functional form model (1980).

MATERIALS AND METHODS

Thalli of *Ulva lactuca* Linnaeus, *Ganonema farinosum (*J. V. Lamouroux) K.C. Fan and Yung C. Wang *Hydropuntia edulis* (S.G. Gmelin) P.C. Silva were collected by hand at intertidal zones of Bing's Resort, Bolinao, Pangasinan while *K. striatum* (F. Schmitz) Doty ex P.C. Silva (Schmitz) at Barangay 2, Calatagan, Batangas (Figs. 2-3). These species were subjected to photosynthesis-irradiance (P-I) experiment following the procedure of Ganzon-Fortes (1997) developed from the method of Dawes (1989; 1992). The Pn_{max} in terms of the amount of oxygen gas fixed per gram dry weight per hour (mg O_2 g dwt^{-1} hr^{-1}) was computed using the equation below:

$$\text{Pnmax (mg O2 g dwt} - 1\text{ hr} - \mathbf{1}) = \frac{\left(\begin{matrix}\text{final O2 - initial O2}\\ \text{per bottle}\end{matrix}\right) - \left(\begin{matrix}\text{final O2 - initial O2}\\ \text{of blank bottle}\end{matrix}\right)}{\text{dry wt (g) of samples per bottle}} /hr$$

Curve fittings of computed Pn_{max} with measured light intensities were done in SYSTAT. The P_{max} and other P-I parameters e.g. Ic, Ik, were calculated using the hyperbolic tangent model of Chalker *et al*. (1983) whilst the curves were generated from Microsoft Excel utilizing the curve-fitted Pn_{max} values.

RESULTS AND DISCUSSION

Among macroalgal species, *U. lactuca* obtained the highest P_{max} (photosynthesis at light saturation) value at 61.8mg O_2 g dw^{-1} hr^{-1} followed by *H. edulis* then *K. striatum* and lastly, *G. farinosum* with the values of 15.2, 14.6 and 9.0 mg O_2 g dw^{-1} hr^{-1}, respectively. The sequence, in a way, elucidated growth form- productivity relationship. The *U. lactuca*, being sheeted in form, had the highest oxygen production rate over the branching-form species, the *H. edulis, K. striatum*, and *G. farinosum* (Table 1).

A relatively higher productivity rate of seaweeds with sheeted and/or thin thalli is a common observation. Littler and Littler (1980) attributed the sheeted form to the opportunistic nature of such morpho-type of macroalgae and their physiological advantage in harvesting light due to minimal self-shading by non-photosynthetic wall components.

According to Littler (1979) and Littler and Murray (1974), the relationship between growth-form and productivity applies to a broad habitat and latitudinal ranges and shows no connection with macroalgal division. In contrast, King and Schramm (1974) noted an obvious trend in favour of Chlorophytes over Phaeophytes and Rhodophytes. Habit, habitat, season and the interplay of those would explain the observed trend.

Result of the study likewise suggested that growth form-productivity hypothesis did not work well with *G. farinosum*, a finely branched species, which was expected to have had a higher P_{max} than the coarsely branched *K. striatum*. The *G. farinosum* although finely branched is slightly calcified. Calcified or articulated seaweeds contain a relatively higher percentage of $CaCO_3$, which is directly associated with non-pigmented or caloric component of the seaweeds (Murray and Littler, 1978; Littler and Littler, 1980). In *Corallina officinalis* for instance, skeletal $CaCO_3$ reaches 81.78% whilst in *Egregia menziesii*, 82.9%. A small discrepancy in percentage of non-photosynthetic component between and among calcified seaweeds as in the case of the two seaweeds mentioned would likely favour growth-form hypothesis (Littler and Littler, 1980).

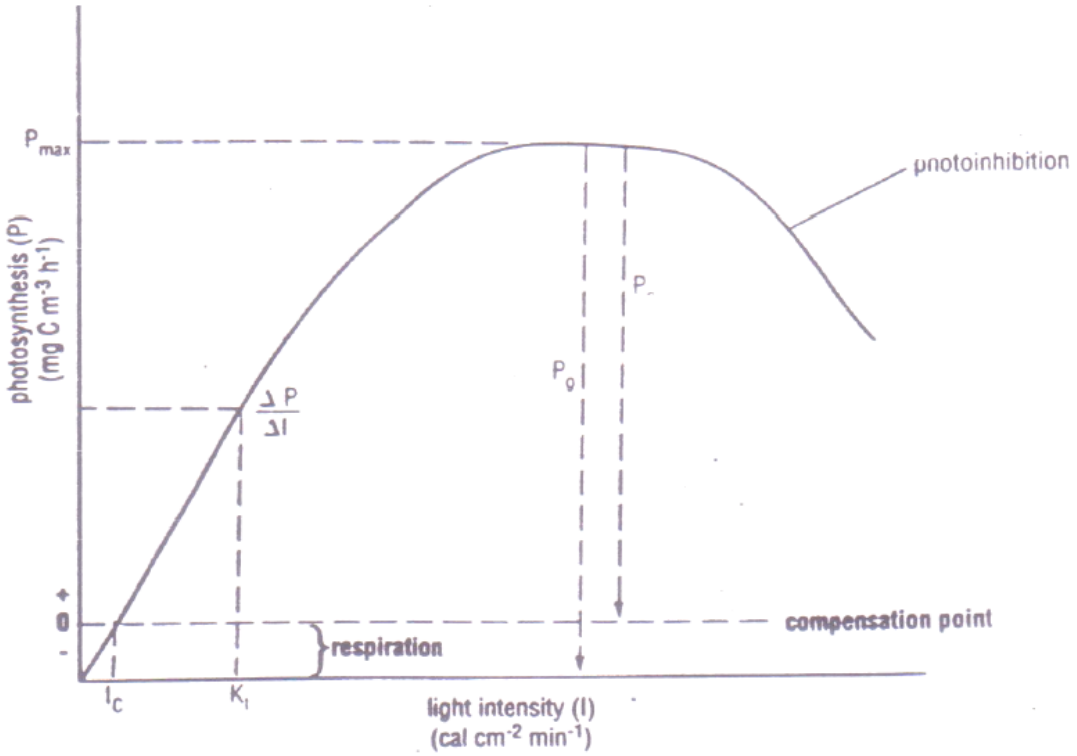

Figure 1. The typical P-I curve showing the response of photosynthesis (P) to changes in light intensity (I). Pmax, maximum photosynthesis; I_c, compensation light intensity; K_I, half saturation constant; P_g, gross photosynthesis; P_n, net photosynthesis (Lalli and Parsons, 1993).

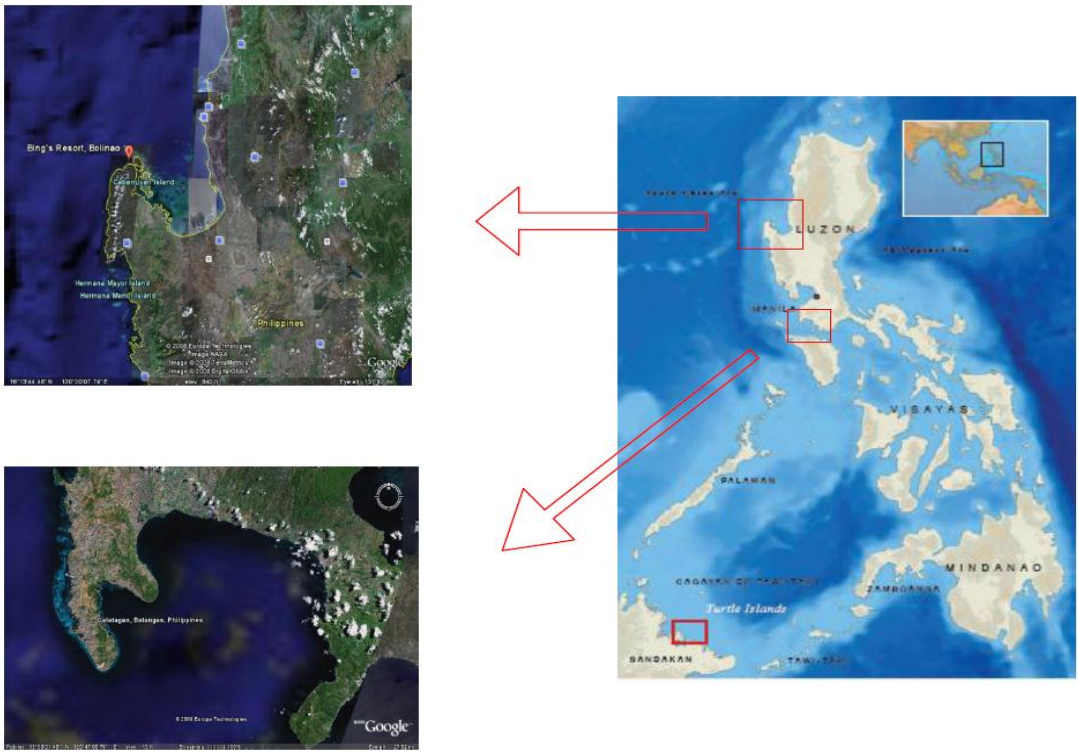

Figure 2. Maps showing the location of Bing's Beach Resort, Pangasinan and Barangay 2 Cove, Calatagan, Batangas (from www.google.earth.com).

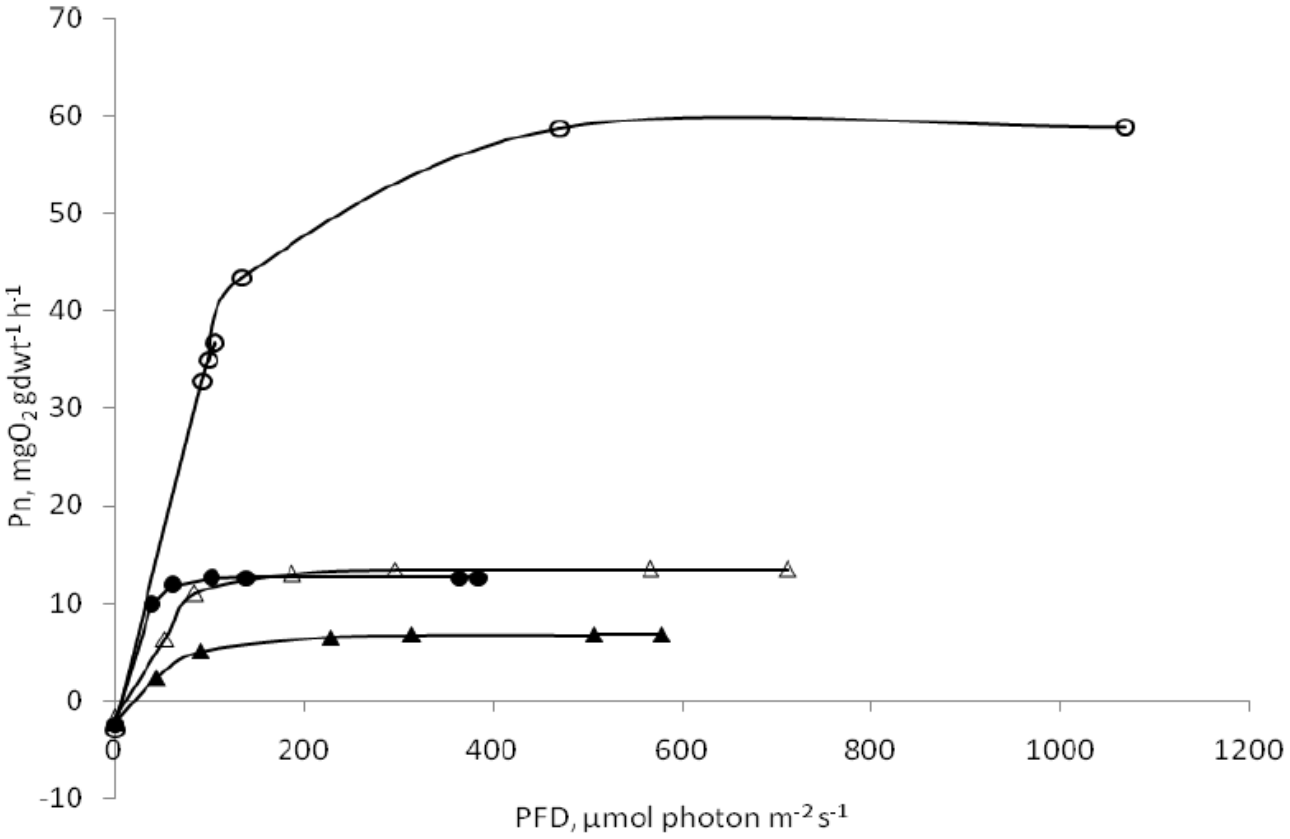

Figure 3. P-I curves of the four macroalgal species: *U. lactuca* (open circle); *K. striatum* (close circle); *H. edulis* (open triangle) and *G. farinosum* (close triangle).

CONCLUSIONS AND RECOMMENDATIONS

The rate of oxygen gas (O_2) production among the studied seaweeds is species-dependent and is primarily affected by the degree of area-to-volume ratio and calcification. Other parameters e.g. temporal and spatial variations in O_2 production, seaweed chlorophyll content, latitudinal range of distribution, and adaptive strategies, among others should also be accounted for more conclusive findings.

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