

# THE IMPORTANCE OF PHOTOSYNTHESIS IRRADIANCE (P-I) CURVE FOR ESTIMATING PRIMARY PRODUCTION BY PHYTOPLANKTON WITH RESPECT TO MIXED DEPTHS

Saitama University & Brandenburg University of Technology, Student Member, ○Jayatu Kanta Bhuyan  
Saitama University, Regular Member, Eiichi Furusato  
Brandenburg University of Technology, Marion Martienssen  
Brandenburg University of Technology, Brigitte Nixdorf  
Japan Water Agency, Regular Member, Hiroomi Imamoto

## 1. INTRODUCTION

Photosynthesis-irradiance (P-I) relationship is the basic fundamental to estimate the production of phytoplankton. The shape and properties of the curve relating light and photosynthesis has been the subject of considerable study. Harmful cyanobacteria cause growth of algal blooms in a water body and thus this is a very important subject to be considered in water environmental management (Furusato and Asaeda, 2004). This paper discusses on the importance and effect of P-I curves for estimating primary production by phytoplankton with respect to mixed depths.

## 2. METHODS

### 2.1 Review of previous definitions of P-I curves

During several decades, many equations have been proposed to describe the relationship between photosynthesis rate ( $P$ ) and incident light intensity ( $I$ ). The models discussed here are to describe the effect of photosynthesis on increasing light intensity and then comparing with the depth integrated net photosynthesis ( $DINP$ ). Four models commonly used empirical P-I equations are considered (Table 1). These are given by Baly (1935), Steele (1962), Webb et al. (1974) and Jassby & Platt (1976) which were compared with respect to goodness to fit, as has been accomplished by Graham B. McBride (McBride, 1992) and Jassby and Platt (Jassby & Platt, 1976).

Fig. 1 shows the P-I relationship curve according to the different models. The notations used to generate these curves are given in Table-2. The initial slope has been given the same for the P-I curves at low light intensity ( $\alpha$ ). The slope is represented as  $\alpha (=P_m/I_s)$ , where the saturation onset parameter  $I_s$  (Kirk, 1983) is the point where the initial slope coincides ( $I_{opt}$  for Steele's model (Steele, 1962)) with  $P_m$  (the maximum photosynthesis rate in the absence of photoinhibition). The initial slope is also  $\alpha$ , when photoinhibition is present, which means that the equation of Steele (Steele, 1962)

can be written in terms of  $P_m$  and  $\alpha$ . The parameters ( $P_m$ ,  $\alpha$ , and  $I_s$ ), are not to vary with depth or throughout the day (McBride, 1992) because these are biological and physiological parameters.

Table 2: Notation and parameters

Notation	Parameters	Units
$I$	Photosynthetically available radiation (PAR)	$\mu\text{E m}^{-2} \text{s}^{-1}$
$I_s$	Saturation onset parameter ( $I_{opt}$ for Steele's model)	$\mu\text{E m}^{-2} \text{s}^{-1}$
$I_0$	Incident ray	$\mu\text{E m}^{-2} \text{s}^{-1}$
$P$	Photosynthesis rate	$\text{d}^{-1}$
$P_m$	Maximum photosynthesis rate	$\text{d}^{-1}\text{ay}$
$z$	Depth	m
$\alpha$	Initial slope of P-I curve, $P_m / I_s$	$\text{m}^2 \text{s} (\mu\text{E})^{-1} \text{d}^{-1}$
$z_m$	Mixed depth	m
$\varepsilon$	Attenuation coefficient	$\text{m}^{-1}$

Table 1: Four Photosynthesis P-I light equations

Equations	Authors	Form
$P = P_m \left[ \frac{I}{I + I_s} \right]$	Baly 1935 (B35)	Rectangular Hyperbola
$P = P_m \left[ \frac{I}{I_{opt}} e^{(1-I/I_{opt})} \right]$	Steele 1962 (ST62)	Exponential
$P = P_m [1 - e^{(-I/I_s)}]$	Webb et. al, 1974 (W74)	Exponential
$P = P_m \tanh \left( \frac{I}{I_s} \right)$	Jassby and Platt 1976 (JP76)	Hyperbolic Tangent

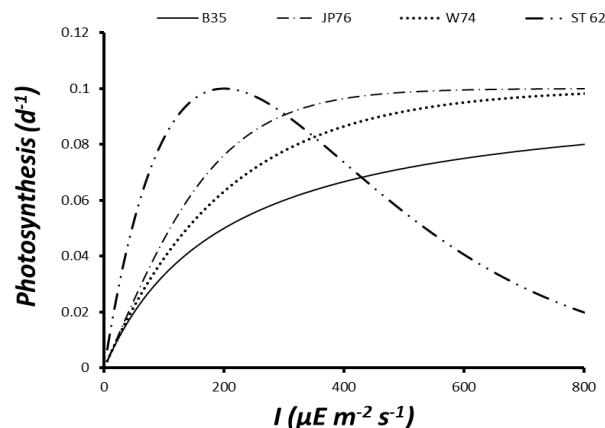


Figure 1 General form of the four P-I equations

Keywords: P-I Curves, Depth Integral Net Photosynthesis, Mixed Depths

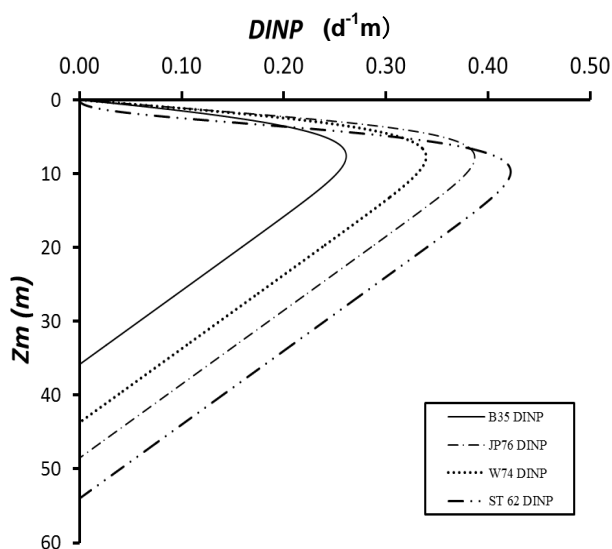
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## 2.2 Characteristics of Previous P-I curves

From **Fig. 1**, we have seen the difference in the characteristics of P-I curves. The main difference are photosynthetic rate under low light intensity conditions which being subsurface layer around euphotic depths. According to the index Hyperbolic Tangent is clearly superior to the rest of the models (Jassby & Platt, 1976). Webb et al., 1974 is the next most useful, but it fell substantially behind the hyperbolic tangent. In any individual experiment, differences in the error variance between some of the curves may not have been significant. The worst fit is given by Baly's equation (Baly, 1935). But among all the models the most widely used in all phytoplankton ecology is Baly's equation. Because of the frequent application of this function, in analogy with Michaelis-Menten enzyme kinetics, to describe nutrient uptake by phytoplankton, the temptation has been strong to extend its use to describe other phenomena, including photosynthesis (Jassby & Platt, 1976). The other popular equation which proved to be inadequate is Steele's equation (Steele, 1962). The reason is that photoinhibition is built (P-I curve) into the equation in such a way that the photosynthetic response below the inhibition threshold is not independent of the response above the threshold. The result is that, if  $\alpha$  used represents the true initial slope, the equation exhibits inhibition for irradiances which are too low. If Steele's equation is modified to exclude the possibility of inhibition a far superior fit is obtained, but this contradicts the original intent of the model (Jassby & Platt, 1976).

## 2.3 DINP (Depth Integral Net Photosynthesis)

In natural water body, phytoplankton cells are being transported in mixed depth. *DINP* should be considered to estimate *in situ* photosynthesis. The Beer-Lambert's Law,  $I(z) = I_0 e^{(-Kz)}$  is used to P-I equations for calculating *DINP*.



**Figure 2: DINP curves with respect to mixed depths according to the models represented in Table 1**

## 3. RESULTS AND DISCUSSIONS

**Fig. 2** shows the *DINP* based on the P-I equations (**Table 1**). The difference of *DINP* among selected P-I equations are remarkable. In particular, common model (Baly, 1935) results in most underestimate *DINP*. Most of light intensity in mixed layer is unsaturated level of photosynthesis. So the characteristics and effects of different P-I curves should be focused for estimating not only *in situ* phytoplankton dynamics but also *DINP*.

## 4. CONCLUSION

Although several P-I equations and *DINP* values are calculated, each describes curvature in a different way, according to its nature. Finally, in estimating the effect of P-I curve various conditions should be considered. From this paper it is concluded that different P-I curve equations gives different *DINP* curves with respect to mixed depths, which is an important factor for estimating primary production by phytoplankton. In the future for estimating critical depth the importance and effect of P-I curves and *DINP* should be considered and discussed.

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