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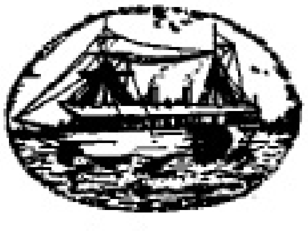

The Investigator

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EXPERIMENTAL ECOLOGY OF TROPICAL MARINE PHYTOPLANKTON

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ABSTRACT

Experiments dealing with the influence of three environmental factors namely light, salinity and nutrients on the photosynthesis of laboratory cultures indicate that the light requirement for optimum photosynthesis in tropical phytoplankton is much greater than that of temperate forms. At saturating light intensity, photosynthesis seems independent of wavelength. Maximum photosynthesis in many organisms occurs at low salinity which seems an adaptation to regulate their peak production during the monsoon months when nutrients in the nearshore waters are high and salinity is low. Growth kinetics and nutrient requirements of **Biddulphia** and **Ceratium** indicate that **Biddulphia** has a higher value of half saturation constant (K_s) than that of **Ceratium.** The former becomes abundant during the monsoon months when the nutrients in the environment are high, and the latter, with a lower K_s, becomes a better competitor at low concentrations of nutrients found during the pre-monsoon months.

INTRODUCTION

The measurements of a set of environmental factors in the sea along with phytoplankton productivity can give only broad relationship between the two. Our inability to relate, very often, the results properly is because many of the finer details on which the activity of phytoplankton is based are still unknown. Therefore, precise experimental work on isolated environmental factors with laboratory cultures is perhaps what remains the only satisfactory approach of determining the optimum effect of one factor or the limitation imposed by the other. The ecological implications of such experiments can easily be tested by field data. Thus, the purpose of this communication is to summarize the results of laboratory studies undertaken on tropical phytoplankton and to draw generalizations of ecological significance. The factors taken into consideration here are: (a) light (b) salinity and (c) nutrients.

MATERIAL AND METHODS

Experiments with light: Laboratory cultures of several species of diatoms and dinoflagellates were taken, and equal quantities of each organism were innoculated in bottles containing Millipore-filtered sea water. The bottles were clamped in an incubator provided with graded neutral density filters. The incubator was exposed to sunlight and the rate of phytosynthesis in each bottle was measured by ^{14}C assimilation. The incident light falling on each bottle was measured by a calibrated lux-meter and the results were expressed as the intensity effect of light on photosynthesis. Each experiment was conducted for a duration of 2 hours.

In addition to the intensity effect, the quality effect of light was also investigated. Bottles containing each organism were exposed to a portion of the visible spectrum, starting from the longest wavelength. Sharp cut-type glass filters were used in a specially designed incubator for cutting off the transmittance of light (for detail see Qasim et al., 1972 *a*).

Experiments with salinity: Each organism was innoculated in bottles containing sea water of varying salinities, from 5-35‰, and the bottles were exposed to constant illumination of 7 kilolux for 3-4 hours. The rate of photosynthesis under each salinity was determined by ^{14}C uptake (see Qasim *et al.*, 1972 *b*).

Experiments with nutrients: Nutrient-depleted cells of two organisms—a diatom, *Biddulphia sinensis* and a dinoflagellate, *Ceratium furca*—were innoculated in 4 litres of Millipore-filtered sea water containing varying concentrations of phosphate and nitrate, either singly or in combination. From each flask, 50 ml aliquots were drawn at regular intervals and these were incubated for 3 hours under constant illumination and their rates of photosynthesis were measured by ^{14}C assimilation (see Qasim *et al.*, 1973).

RESULTS AND DISCUSSION

Influence of light

Fig. 1 gives the rate of photosynthesis in two organisms (*Biddulphia sinensis* and *Ceratium furca*) as a function of light intensity. As can be seen from the figure, each curve is divisible into three portions—the linear portion of the relationship at low light intensity, the portion of less rapid increase or plateau which indicates optimum photosynthesis at light saturation, and the portion of progressive inhibition of photosynthesis at high light intensity. The point of intersection between linear and saturation regions, which is shown by the I_k, is the point from where the onset of light saturation occurs. In *Biddulphia*, the I_k was at about 17.5 kilolux and in *Ceratium*, it was approximately 13.0 kilolux. Similarly, 10 more organisms were subjected to changes in light intensity and their I_k values were determined. These ranged between 11-18 kilolux, excepting in *Rhizosolenia styliformis* and *Dinophysis miles*, where the I_k values were exceptionally high—23.5 and 34.5 kilolux respectively (Qasim *et al.*, 1972 *a*).

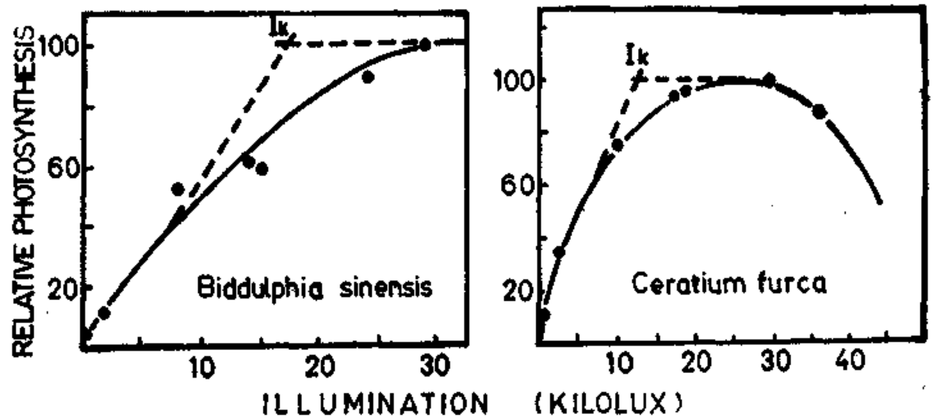

Fig. 1. Photosynthesis in two organisms as a function of light intensity. The point of intersection (I_k) in each curve indicates the point of the onset of photosynthesis at light saturation.

Fig. 2 gives the rate of photosynthesis as a function of illumination in two natural phytoplankton populations taken from the Cochin Backwater (see Qasim *et al.*, 1969). The relationship was almost similar to that of the laboratory cultures and the I_k values in these two cases were found to be 13.6 and 20.8 kilolux.

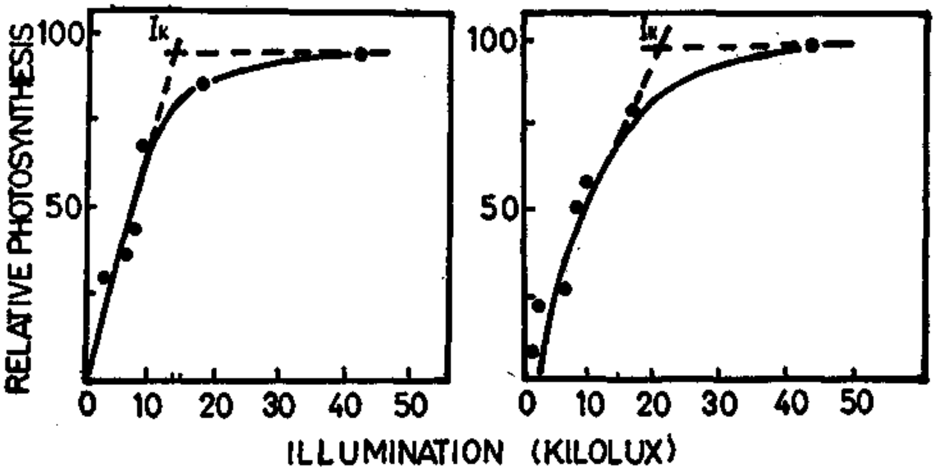

Fig. 2. Photosynthesis in relation to light intensity in two samples of natural phytoplankton population taken from the surface of Cochin Backwater. The I_k values indicate the saturation points in relation to illumination.

The quality effect of illumination on the photosynthesis of ***Biddulphia*** and *Ceratium* has been shown in Fig. 3. Maximum photosynthesis in both the organisms occurred in the spectral range 700-402 mμ and 700-430mμ. The rate of photosynthesis in both the organisms for the entire visible spectrum 700-400mμ declined because the intensity was too high. The photosynthetic rates in several other organisms in response to quality effect was almost similar to those shown by *Biddulphia* and *Ceratium*. There was no dependence on wavelength in saturating light (Qasim *et al.*, 1972 *a*).

When the photosynthetic rates of the two organisms were plotted against the radiant energy transmitted through the sharp cut-type filters (Fig. 4), the curves obtained were similar to those of the intensity effect, that is, a linear phase at low energy, a saturation phase at optimum energy and an inhibition phase at higher energy (compare Fig. 4 with Fig. 1). This indicates that as long as the light energy available is optimum for photosynthesis (saturation intensity), almost all regions of the visible spectrum are effective.

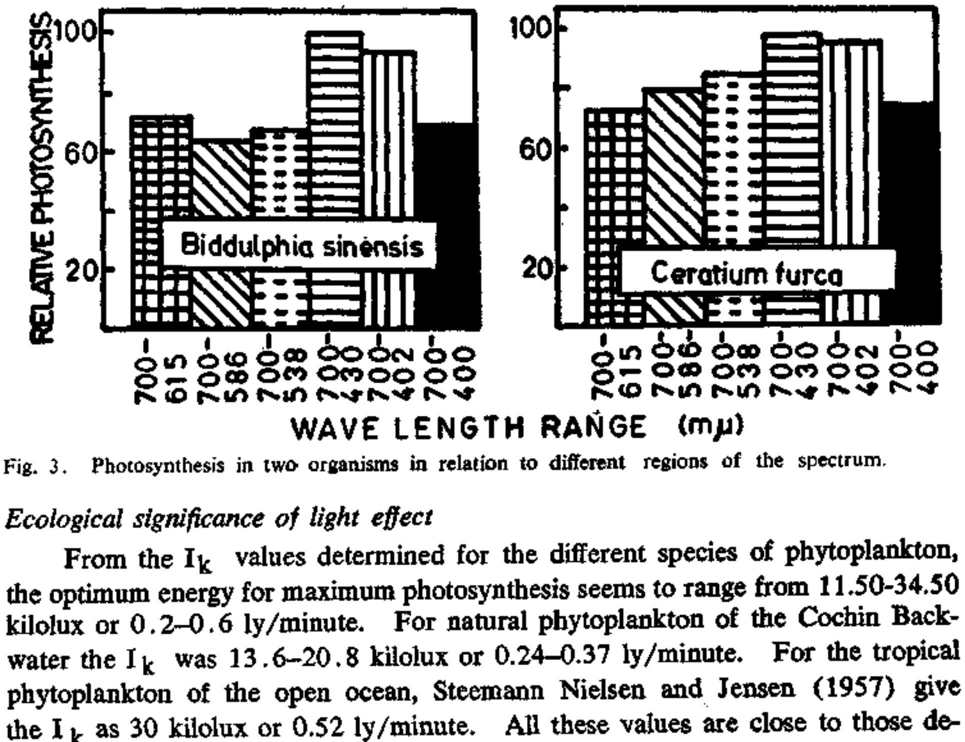

Fig. 3. Photosynthesis in two organisms in relation to different regions of the spectrum.

Ecological significance of light effect

From the I_k values determined for the different species of phytoplankton, the optimum energy for maximum photosynthesis seems to range from 11.50-34.50 kilolux or 0.2–0.6 ly/minute. For natural phytoplankton of the Cochin Backwater the I_k was 13.6–20.8 kilolux or 0.24–0.37 ly/minute. For the tropical phytoplankton of the open ocean, Steemann Nielsen and Jensen (1957) give the I_k as 30 kilolux or 0.52 ly/minute. All these values are close to those determined by experiments. These experiments also indicate that the optimum light requirement of the tropical phytoplankton is much greater than that of the temperate forms. The average solar radiation falling on the sea surface at Cochin during the year ranges from 205-550 ly/minute. Thus even in highly turbid environments such as the Cochin Backwater, where the light penetration is greatly reduced, optimum illumination is available within a few metres from the surface (Qasim *et al.*, 1968).

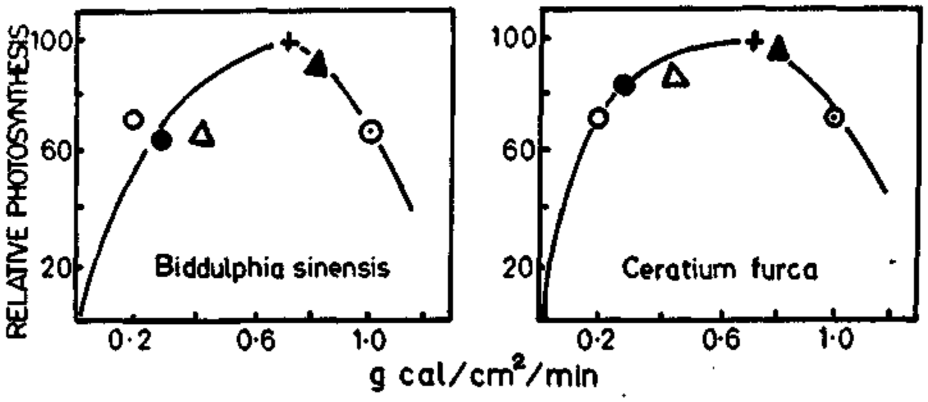

Fig 4. Photosynthesis in two organisms in relation to total energy available at different wavelengths of the spectrum. ○, 700-615 mμ; ●, 700-586 mμ; △, 700-538; +, 700-430 mμ; ▲ 700-402 mμ; ◎ , 700-400 mμ.

Photosynthetic response shown by the different organisms in response to quality of light indicates that phytoplankton quickly adapt themselves to changing light conditions. Such a chromatic adaptation is of distinct advantage to marine phytoplankton which have a floating existence. With rapid changes in depth, the light conditions also change, but the photosynthesis would not be affected much, even when a portion of the spectrum is cut-off.

Influence of salinity

The rates of photosynthesis in *Biddulphia* and *Ceratium* at different salinities have been shown in Fig. 5. In *Biddulphia*, the highest rates were obtained at salinities 10-20‰, but in *Ceratium* maximum photosynthesis occurred at still lower salinities, 6–10‰.

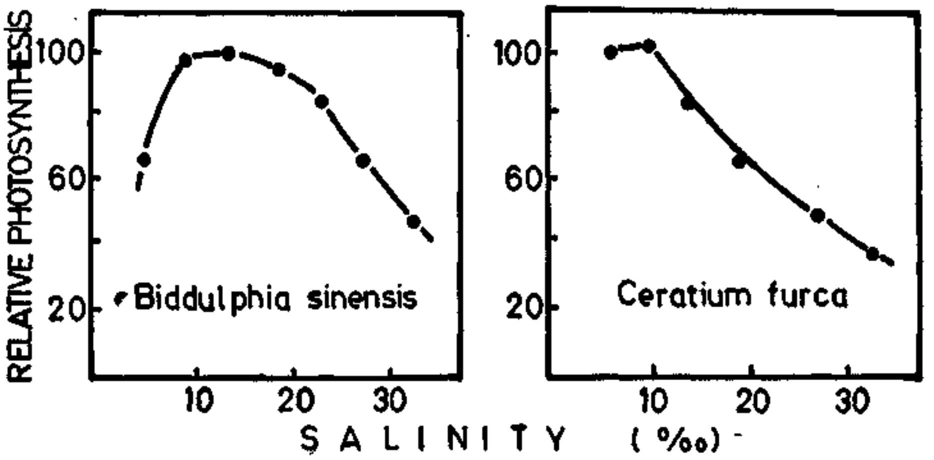

Fig. 5. Photosynthesis in two organisms as a function of salinity.

Ecological significance of salinity effect

The reduction in salinity along the south-west coast of India, induced by the heavy rainfall during the monsoon months, is very well marked and occurs every year. Along the south-east coast also, changes in salinity are brought about by the discharge of fresh water by many large rivers into the Bay of Bengal. This would mean that reduction in salinity in the coastal waters of India is associated with the enrichment of water with nutrients. The adaptation in phytoplankton for maximum photosynthesis in response to low salinity, is therefore so adjusted as to ensure their peak production during a time when high concentrations of nutrients are available in the environment. In the Cochin Backwater, where changes in salinity are very wide, many organisms have been found to bloom successively at exceptionally low salinities (Qasim *et al.*, 1972 b). These observations confirm that waters of low salinity support a greater abundance of phytoplankton in nature.

Influence of nutrients

Growth rates of *Biddulphia* and *Ceratium* as a function of nutrients followed the enzyme kinetics similar to that of Michaelis-Menten equation of bacterial growth (see Dugdale, 1967; Eppley and Thomas, 1969; Thomas, 1970). This equation has the form

$$\mu = \mu\text{max}\left(\frac{S}{K_s + S}\right)$$

where μ is the specific growth rate of algae, μmax is the maximum growth unlimited by low nutrient concentration, S is the nutrient concentration and K_s is the half saturation constant, which is equal to μmax/2

Specific growth rate μ when plotted against μ/s gave the values of K_s and μmax graphically (see Qasim *et al.*, 1973). Table 1 gives the values of K_s and μmax of *Biddulphia* and *Ceratium*. Both the organisms have low K_s for phosphate and a high K_s for nitrate. When the two nutrients are used in combination, the K_s for *Biddulphia* becomes still lower but in *Ceratium* the K_s obtained is almost average of those for phosphate and nitrate. The μmax values in both the organisms were independent of high or low values of K_s (Table 1).

Ecological significance of nutrient effect

Both the organisms, *Biddulphia* and *Ceratium* are neritic species and are found in estuaries and inshore waters, where nutrients normally occur in high

TABLE 1. *Values of half saturation constant* (K_s) *and maximum growth rate* (μmax) *obtained for Biddulphia sinensis and Ceratium furca in enrichment experiments*

	Biddulphia sinensis			*Ceratium furca*		
	Phosphate	Nitrate	Phosphate + Nitrate	Phosphate	Nitrate	Phosphate + Nitrate
K_s	0.17	0.74	0.10	0.15	0.44	0.24
μmax	0.65	1.05	0.87	1.38	1.87	1.38

concentrations. In the Cochin Backwater, *Ceratium* is found in fairly large concentrations during the premonsoon months (March-April) when the nutrients are low. *Biddulphia,* on the other hand, becomes abundant during the monsoon months when nutrients reach maximum concentrations. *Ceratium* has a low K_s and therefore it is a better competitor at low concentrations of nutrients. When the nutrients become high, *Ceratium,* despite its lower salinity tolerance, is unable to compete with *Biddulphia* which has a higher K_s. The growth kinetics of the two organisms thus provide an explanation of the observed seasonal succession of the two species.

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