2008 Circumpolar Flaw Lead (CFL) System Study

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Photosynthesis-Irradiance Incubations

Photosynthetic characteristics were obtained from photosynthesis-irradiance (P-E) measurements using a modification of the ^{14}C bicarbonate technique of Lewis and Smith (1983) as modified by Arrigo et al. (2010). P-E incubations were carried out at 2°C and at 20 irradiances ranging from 0 to 635 µmol quanta m^{-2} s^{-1}. The incubator was an aluminum block containing illumination chambers to hold the incubation vials and channels through which coolant was continuously circulated. Even illumination was provided to each incubation chamber via a fiber optic cable connected to an illuminator (Lumenyte International Corporation, model DMX512) fitted with a 150 W tungsten-halogen lamp. Total photosynthetically available radiation (PAR, 400-700 nm) within each illumination chamber was measured using a Spherical Micro Quantum Sensor US-SQS (Heinz Walz, GmBH). Spectral irradiance, $E(\lambda)$, was measured from 300-800 nm using a spectroradiometer (Analytical Spectral Devices, FieldSpec).

For each P-E curve, a 50 ml sample of stock culture was placed in a pre-chilled, 200 ml plastic beaker and spiked with 0.925 MBq $H^{14}CO_3$ to obtain a final activity of 0.019 MBq ml^{-1}. After thorough but gentle mixing, the spiked sample was distributed in 2 ml aliquots to 23 pre-chilled 20 ml plastic (polyethylene terephthalate) scintillation vials. Twenty of these vials were placed in individually illuminated chambers within the incubator and the incubation was initiated by turning on the light source. The contents of the three remaining vials (time-zero samples) were acidified with 100 µl of 6N HCl to drive off inorganic carbon and determine the background particulate radioactivity levels. To determine total radioactivity in the spiked sample, three 100 µl aliquots of spiked sample were added to scintillation vials containing 0.5 ml filtered seawater, 5 ml of scintillation fluid (EcoLume) and 100 µl of ethylamine and then assayed for radioactivity by liquid scintillation counting (Perkin Elmer WinSpectral 1414). Incubations were terminated after 1 h by turning off the light source and adding 100 µl of 6N HCl to each vial. All acidified samples were gently shaken for a minimum of 12 h to drive off radioactive inorganic carbon and then neutralized with 100 ml of 6N NaOH and mixed with 10 ml scintillation fluid. Radioactivity was determined by liquid scintillation counting.

The P-E parameters were derived from a fit of P-E data to the equation of Platt et al. (1980)

$$P^* = P_s^*(1 - e^{-\alpha^* E / P_s^*})e^{-\beta^* E / P_s^*} - P_0^* \tag{1}$$

where P^* is the photosynthetic rate at irradiance E, P_s^* is the light-saturated photosynthetic rate in the absence of photoinhibition, α^* is the initial slope of the P-E curve, β^* is a measure of photoinhibition, and P_0^* is the CO_2 uptake or release at E = 0 µmol quanta m^{-2} s^{-1}. The superscript * indicates that the term is normalized to Chl *a*. For POC-normalized parameters, the superscript * is replaced with *C*.

P_m^*, the maximum realized photosynthetic rate (photosynthetic capacity), was calculated as

$$P_m^* = P_s^* \left(\frac{\alpha^*}{\alpha^* + \beta^*} \right) \left(\frac{\beta^*}{\alpha^* + \beta^*} \right)^{\beta^*/\alpha^*}. \tag{2}$$

The photoacclimation parameter E_k, is calculated as P_m^*/α^*.

Particulate absorption

Specific absorption coefficients. Microalgae were filtered under low vacuum pressure onto glass fiber filters (Whatman GF/F) and particulate absorption spectra ($a_p(\lambda)$, m^{-1}) were measured between wavelengths of 300 nm and 800 nm using a Perkin-Elmer Lambda 35 spectrophotometer following the method of Mitchell and Kiefer (1988). Detrital absorption spectra ($a_d(\lambda)$, m^{-1}) were determined for each $a_p(\lambda)$ spectra using the methanol extraction technique of Kishino et al. (1985). All $a_p(\lambda)$ and $a_d(\lambda)$ spectra were corrected for optical path amplification using the procedure of Mitchell and Kiefer (1988) and the coefficients of Bricaud and Stramski (1995). Chl *a*-specific phytoplankton absorption spectra ($a^*_{ph}(\lambda)$, m^2 mg^{-1} Chl *a*) were calculated by subtraction of $a_d(\lambda)$ from $a_p(\lambda)$ (Roesler et al. 1989) and normalized to fluorometrically determined Chl *a* concentrations.

The spectrally weighted mean Chl *a*-specific absorption coefficient for phytoplankton ($\bar{a}^*$, m^2 mg^{-1} Chl *a*) was calculated using the equation

$$\bar{a}^* = \frac{\sum_{400}^{700} a^*_{ph}(\lambda)\, E(\lambda)}{\sum_{400}^{700} E(\lambda)} \tag{3}$$

where $E(\lambda)$ (µmol quanta m^{-2} s^{-1}) is the spectral irradiance of the P-E incubator.

Determination of the maximum quantum yield of photosynthesis (Φ_m) depended upon the light level at which the maximum Φ_m was measured. Most models assume that Φ_m is achieved at the lowest irradiances, although this assumption does not always hold (Johnson and Barber 2003). Therefore, we first determined Φ at each photosynthetron light level (Φ_E) from $\bar{a}^*$ and the Chl *a*-normalized CO_2 uptake (P^*) using the equation presented in Johnson and Barber (2003)

$$\Phi_E = \frac{P_E^*}{43.2\ \bar{a}^*\, E} \tag{4}$$

where Φ_E is the calculated quantum yield of photosynthesis at each of the 20 irradiance levels (E) produced in the photosynthetron, P^*_E is the photosynthetic rate at irradiance E, and 43.2 is a unit conversion factor. When the assumption that Φ_m was maximal at the lowest light level was not met, Φ_m was chosen as the maximum value for Φ_E attained within the range of values of E used in the photosynthetron. When Φ_E was inversely related to irradiance, we calculated Φ_m using the equation

$$\Phi_m = \frac{\alpha^*}{43.2\ \bar{a}^*}. \tag{5}$$

Unit Definitions:

P^*_m: mg C mg^{-1} Chl *a* h^{-1}
Alpha* (α^*) and Beta* (β^*): mg C mg^{-1} Chl *a* h^{-1} (umol quanta m^{-2} s^{-1})$^{-1}$

Ek: umol quanta m^{-2} s^{-1}
Quantum Yield (Φ_E or Φ_m): mol C mol^{-1} quanta
Mean specific absorption coefficient ($\bar{a}^*$): m^2 mg^{-1} Chl *a*

Sample Type Definitions:
UISW: Under ice surface water (<2 m deep)
UI SCM: Under ice subsurface chlorophyll maximum
OW SCM: Open water subsurface chlorophyll maximum

References

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