Parameters

From an ecological perspective, the quantum efficiency or yield (F_v/F_m), along with other parameters, can be used to determine how much solar energy can be converted to fixed carbon. The yield is a parameter that describes how well phytoplankton can assimilate light or photosynthesize. Aquatic researchers can use this information to evaluate the health of ecosystems and associated variables that indirectly or directly affect phytoplankton physiology in both marine and freshwater systems. Active fluorescence parameters (F_o, F_m, F_v, yield) can be collected and interpreted for baseline data, as a comparative tool or as an early sign of system change.

Data Variability

The following describes normal variability associated with parameters determined on the PhytoFlash. The PhytoFlash data rate is 230 Hz, providing increased resolution. Figure 1 shows typical variability for blank (artificial seawater) samples as well as a green algal monoculture (Dunaliella). The magnitude of variability is influenced by algal species, particulates in the sample and refractive light.

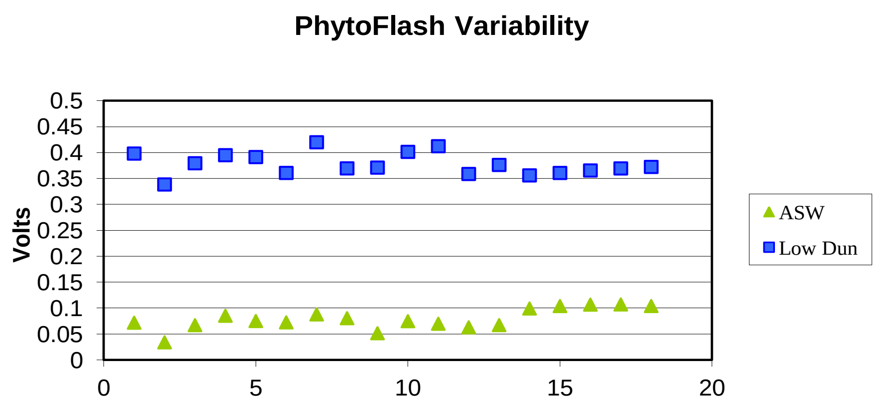

Figure 1.

$CuSO_4$ Affect on the Yield in an Enclosed Experiment

Copper sulfate ($CuSO_4$) was used in an experiment designed to demonstrate the change in yield in relation to an "impacted" system. $CuSO_4$ impacts algal cells by inhibiting specific mechanisms of photosynthesis. Two sub-samples of a green algal monoculture (*Dunaliella*) at a 50 µg/l concentration were prepared. One sample acted as a control and 100 µM of $CuSO_4$ was added to the second sample. Samples were evaluated using the PhytoFlash active fluorometer. The instrument was blanked using artificial seawater (35 psu) for each sample. Samples were measured at 1-minute intervals over a 50-minute period to assess the natural variability of the control culture as well as the effect of $CuSO_4$. At the 4-minute time interval 100 µM of $CuSO_4$ was added to the second culture.

F_v/F_m Response to Copper Sulfate Using the PhytoFlash

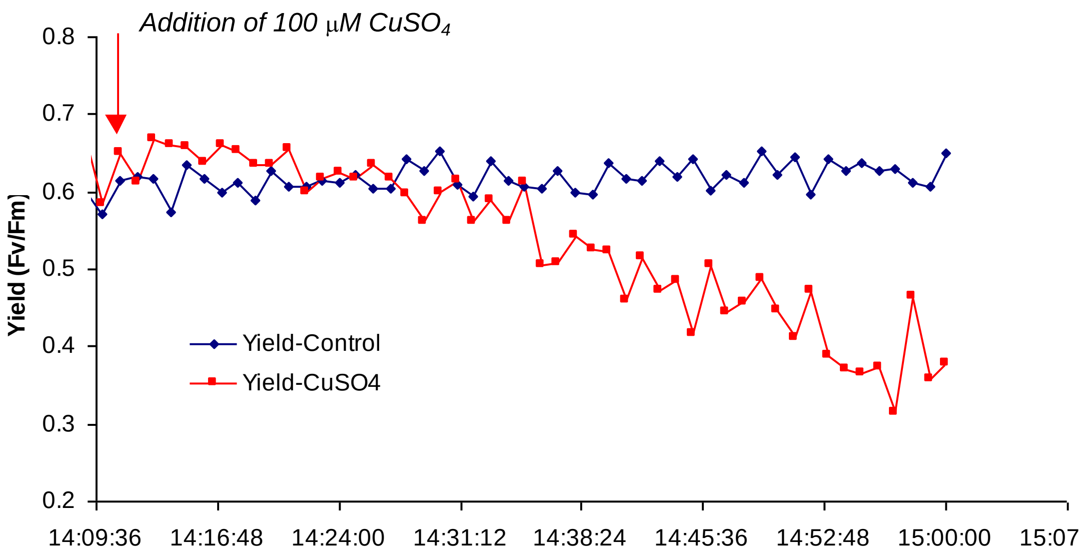

Figure 2.

Yields ranged from 0.588-0.648 for the control sample over 50-minutes displaying natural variability. At approximately 16-minutes after the addition of $CuSO_4$ yields begin to deviate from the natural range of variability. At the end of the experiment (50-minutes) yields dropped significantly to 0.216 for the $CuSO_4$ sample and the control remained above 0.600. The PhytoFlash active fluorometer was able to detect that there was an impact in the system negatively affecting photosynthesis.

Yield (F_v/F_m) Correlated to Nutrient Concentrations

In aquatic sciences, it has been widely accepted that the maximum quantum yield of photosynthesis is influenced by nutrient stress. The maximum quantum yield (F_v/F_m), can be estimated by measuring the increase in fluorescence yield from dark-adapted minimal fluorescence (F_o) to maximal fluorescence (F_m), which is associated with the closing of photosynthetic reaction centers during saturating light or a photosynthetic inhibitor such as 3'-(3,4-dichlorophenyl)-1',1'-dimethyl urea (DCMU). Therefore the F_v/F_m ratio is as an indicator of nutrient stress. Published results indicate that F_v/F_m is depressed for nutrient-stressed phytoplankton, both during nutrient starvation (unbalanced growth) and acclimated nutrient limitation (steady-state or balanced growth). Under nutrient enriched conditions F_v/F_m is high. This was demonstrated by the Turner Designs PhytoFlash submersible active fluorometer, resulting in high F_v/F_m values (0.55-0.68), for cultures in a steady state under high irradiance.

Most literature supports that F_v/F_m is a good indicator of nutrient stress in transient conditions, common in coastal waters. However, F_v/F_m may not be an optimal indicator in steady-state conditions, such as you would see in oligotrophic gyres. Variable fluorescence measurements can provide evidence that system change has occurred or is occurring leading to the implementation of additional water quality parameters.

Active Fluorescence Applications

- Marine and limnological ecosystem studies
- Early alert for Harmful Algae Blooms
- Indicator of ballast water change
- Indicator of a contamination (i.e. biotoxin)

References

Parkhill, Jean-Paul, G. Maillet, and J. Cullen. 2001. Fluorscence-based Maximal Quantum Yield for PSII as a Diagnostic of Nutrient Stress. *Journal of Phycology* Vol. 37 Issue 4 Page 517.

Cullen, J.C. and R.F. Davis. 2003. The blank can make a big difference in oceanographic measurements. *Limnology and Oceanography Bulletin*. 12(2):29-34.

Cullen, J.J and E.H. Renger, 1979.Continuous measurement of the DCMU-induced fluorescence response of natural phytoplankton populations. *Marine Biology*, vol. 53, 13-20.

Behrenfeld , M.J, A.J. Bale, Z.S. Kolber, J. Aiken and P.G. Falkowski. 1996. Widespread iron limitation of phytoplankton photosynthesis in the equatorial Pacific Ocean. *Nature,* 383: 508-511.

Fuchs, E., Zimmerman, R.C., and J.S. Jaffe, 2002. The effect of elevated levels of phaeophytin in natural water on variable fluorescence measured from phytoplankton. *Journal of Phytoplankton Research*, vol 24(11). 1221-1229.

Furuya, K. and K. William, 1992. "Evaluation of photosynthetic capacity in phytoplankton by flow cytometric analysis of DCMU-enhanced chlorophyll fluorescence" *Marine Ecology Progress Series*, vol. 88: 279-287.

Geider, R.J., R.M. Greene, Z. Kolber, H.L. MacIntyre, and P. G. Falkowski. 1993. Fluorescence assessment of the maximum quantum efficiency of photosynthesis in the western North Atlantic. *Deep-Sea Res*, 40:1204-1224.

Genty, B., J.M. Braintais, and N.R. Baker, 1989. The realtionship between the quantum yield of photosynthetic electron transport and quenching of chlorophyll fluorescence. *Biochim. Biophys. Acta*, vol.990. 87-92.

Gross, R.E., P. Pugno, and W.M. Dugger, 1970. Observations on the Mechanism of Copper Damage in *Chlorella*. *Plant Physiology*, vol. 46, 183-185.

Kirk, J., 1994 Second Edition. Light and photosynthesis in aquatic ecosystems. Cambridge University Press

Kolber, Z. and P.G. Falkowski, 1993. Use of active fluorescence to estimate phytoplankton photosynthesis *in situ*. *Limnology and Oceanography*, vol.38(3) 1646-1665.

Kromkamp, J.C. and R. M. Forster, 2003. The use of variable fluorescence measurements in aquatic ecosystems: differences between multiple and single turnover measuring protocols and suggested terminology. *Eor. J. Phycol*, vol 38. 103-112.

Samuelsson, G. and G. Oquist, 1977. A method for studying photosynthetic capacities of unicellular algae based on *in vivo* chlorophyll fluorescence. *Physiol. Plant*, vol. 40, 315-319.

Schreiber, U., Hormann, H., Neubauer, and C. Klughammer, 1995b. Assessment of photosystem II photochemical quantum yield by chlorophyll fluorescence quenching analysis. *Aust. J. Plant. Physiol*, vol.22. 209-220.