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A new algorithm for the derivation of PSII electron transport rate per unit volume (JVPSII), called “absorption algorithm”, was proposed by Oxborough et al. 2012. In this work, for the first time, we checked whether the growth rate of PC-rich and PE-rich picocyanobacteria is dependent on cumulative diel PSII electron flux (*JV*PSII; µmol e− µmol Chl a−1 d−1).

Based on these calculations, we found that µ, within each strain, show fairly consistent saturating responses to increasing cumulative diel PSII electron flux (*JV*PSII; µmol e− µmol Chl a−1 d−1), although photoperiod and peak PAR retained a secondary influence on achieved growth responses.

@leiVariationPhotosyntheticElectron2018

The earliest method for measuring photosynthetic parameters mentioned above is the “fluorescence induction technique”, which is based on monitoring fluorescence transient of a dark-adapted sample under a short continuous light (Govindjee 1995). But since the excitation transported to RCII in a dark-adapted state is slower than the re-oxidation of PQH2, and also because the stoichiometry of plastoquinone pool (PQ) is about 5-30 times higher than Qa (Kolber and Falkowski, 1993), the fluorescence yield change is complicated due to multiple turnovers of PSII. Afterwards, single-turnover (ST) and multiple-turnover (MT) active fluorescence-based techniques were develop. The duration of MT flashes is long enough to allow several oxidation and reduction steps of Qa, leading to also reduction of Qb and PQ-pools. But the duration of ST flashes only allows a single reduction of Qa. The principle is to expose samples to one or more saturating light flashes, and then record changes in fluorescence yield.

One of the applications of them is the “pulse amplitude modulated (PAM)” (also called “light doubling”) method proposed by Schreiber et al in 198. Another applications is “pump and probe' (P&P)”, advocated by Mauzerall in 1972 and further developed by Kolber and Falkowski (Falkowski et al. 1986; Kolber et al. 1990). They recorded fluorescence yields with weak short probe flash before and after an ST (~10 μs) actinic pump flash of variable intensity.

The subsequently proposed “fast repetition rate fluorescence (FRRF)” by Kolber et al in 1998 is a great improvement, which measures fluorescence changes induced by a series of ST sub-saturating flashlets (~1 μs). Although the intensity of single flashlet is not saturating, the overall photon flux is more than saturating by virtue of the high frequency. The intensity, duration, and interval between them can be controlled independently, allowing separate control of Qa and PQ reduction, and consequently derivation of independent contribution of different processes to the fluorescence yield change. Besides, σPSII and the connectivity among RCIIs can also be calculated from this fluorescence transient kinetics.

@leiVariationPhotosyntheticElectron2018 showed that also means the new absorption algorithm using calculated aLHII to derive PSII electron transport rate per unit volume (JVPSII) is not usable in such unbalanced condition.

@connorInvestigatingUseFast2018

It is possible to determine the physiological state of phytoplankton using changes in the variable fluorescence output from the photosynthetic pathways present in all phytoplankton. Here this was achieved using a Fast Repetition Rate fluorometer (FRRf). Algal dynamics respond rapidly to changes in environmental conditions making it essential that measurements are made as quickly and accurately as possible.

Photosynthesis is traditionally divided into two sets of reactions: the ‘light’ reactions and the ‘dark’ reactions. The ‘light’ reactions consist of the electron and proton transfer reactions through the photosynthetic pathways whereas the ‘dark’ reactions are further down the path at the Calvin cycle , as discussed later, and are responsible for biosynthesis of carbohydrate molecules from CO2 (Whitmarsh and Govindjee, 1995).Oxygenic photoautotrophs utilise two photochemical reaction centres, photosystem II and photosystem I, respectively, to coordinate electrons from the water-splitting reactions through the linear electron transport chain to NADPH. Electrons travel through the linear electron transport chain by electron coupling and FRET interactions between a series of pigment-protein complexes (Behrenfeld et al., 2013). This linear electron transport chain is most commonly visualised using a Z-scheme (Govindjee, 2000), which can be used to track the main stages of the photosynthetic process.

Electrons are stripped from water molecules through oxidation catalysed by a manganese complex. Two molecules of water are required to produce 4 protons, 4 electrons and a molecule of diatomic oxygen. Electrons are then shuttled from the manganese complex to P680 by tyrosine. The excited P680 reaction centre then transfers the electron through phaeophytin to the first stable electron acceptor, a bound plastoquinone molecule (QA). QA is only capable of accepting a single electron at a time, which is then passed to a loosely bound plastoquinone molecule at a separate binding site (QB) along with two protons allowing the molecule to detach as plastoquinone. The plastoquinone (PQ) molecule is mobile through the hydrophobic interior of the thylakoid membrane. These reactions form the light-dependent reactions. Electrons are able to pass between these molecules due to the difference in their respective redox potentials. Molecules at the top of the Z-scheme have a lower redox potential and hence more readily give up electrons to those with a higher redox potential.

Fluorescence as a competitive mechanism is key to our ability to probe the physiological state of phytoplankton. Fluorescence occurs as a singlet to singlet mechanism where two electrons of opposite spin, with one in the excited singlet state and the opposite electron in the ground excited state, pair together. This is described as a spin-allowed process and occurs very rapidly with the fluorescence lifetime (Wong, 2017), i.e. the time between excitation and return to ground state, with this being a physiology-dependent variable.

Fast Repetition rate fluorometry (FRRf) was first mentioned in the literature in 1992 by Zbigniew Kolber and Paul Falkowski in their description of the development of an in vivo instrument for measuring the photosynthetic rates of phytoplankton via fluorescence (Kolber and Falkowski, 1992). FRRf is described as being a minimally invasive and non-destructive means of probing photosystem II of algal cells (Kolber and Falkowski, 1998). The FRRf method takes advantage of the photochemical setup described previously where photolytic separation of water produces electrons, protons and molecular oxygen. Theory behind Fast Repetition Rate fluorometr was described in detail by @connorInvestigatingUseFast2018.

Phytoplankton are on the front line of the effects of anthropogenic climate change. The FRRf is a key tool for establishing algal physiological state and it is essential that protocols for making measurements are based on sound understanding of its performance and the underpinning biology. ccurate measurements of the algal physiological state may prove to be very useful in revealing the impact that a rapidly changing global climate has on our water systems. An ability to measure these changes in algal physiological state accurately and with confidence is a crucial first step in this process.

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@keysEffectFutureCO22018

Photosystem II (PSII) variable chl fluorescence parameters were measured using a Fast Repetition Fate fluorometer (FRRf) (FastOcean sensor in combination with an Act2Run laboratory system (Chelsea Technologies, West Molesey, UK)). The excitation wavelengths of the FRRf’s light emitting diodes LEDs) were 450, 530 and 624 nm. The instrument was used in single turnover mode with a saturation phase comprising 100 flashlets on a 2 μs pitch and a relaxation phase comprising 40 flashlets on a 50 μs pitch. Measurements were conducted in a temperature-controlled chamber at 15 °C. The minimum (Fo) and maximum (Fm) chl fluorescences were estimated according to Kolber et al., (1998).

PSII electron flux was calculated on a volume basis (JVPSII; mol e- m-3 d-1) using the absorption algorithm (Oxborough et al., 2012).

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@ramirezOceanAlkalinityEnhancement2024

Jvpsii does not change under the influence of variable alkalinity

No significant differences were observed between only alkalinity levels in terms of the photosynthetic parameters α-rP and α-JVPSII (volume-specific electron transport) during phase-I or phase-II.

Jvpsii pokazywal istotne roznice w interakcji faza i alkalicznosc.

The cell viability of Synechococcus spp . did not change during 20 day. And remained stable. Powyzej 22 dnia eksperymentu Synechococcus spp. also flourished towards the end of this phase.

This study shows that there is minimal evidence indicating a harmful impact of high alkalinity on the Synechococcus. The OAE treatments did not result in physiological fitness impairment, thus OAE did not cause cellular stress in the phytoplankton community studied.

Synechococus nie wykazywal roznic w cell viabality pod wplywem roznych faz eksperymentu.

roznice w jvpsii moga zalezec od rozmiaru komorki!

@gianniniInfluencePhytoplanktonPigments2016

@gianniniInfluencePhytoplanktonPigments2016 investigated the influence of phytoplankton pigments composition and dominant cell size on fluorescence-derived photo-physiological parameters and implications for primary production rates.

When the variable fluoresce technique is applied to phytoplankton cultures grown in laboratory, the observed values for σPSII have been associated with taxonomic composition, cell size (Suggett et al. 2009) and modes of nutrient supply (Parkhill et al. 2001). In natural phytoplankton communities, Fv/Fm and σPSII also vary with taxonomic composition and cell size but can also respond strongly to photo-acclimation and photo-adaptation (Moore et al. 2006), especially in nutrient-limited environments (Moore et al. 2008; Suggett et al. 2009). Because of that, the relationships between the photo-physiological parameters and natural communities may also vary remarkably with depth. A common observed feature in stratified oceans is the deep chlorophyll maximum (DCM) layer, which is maintained by a number of distinct processes that range from enhanced growth driven by nutrients to selection of photo-adapted and photo-aclimated populations, from eutrophic to oligotrophic environments respectively (Cullen 2015). Thus, the photo-physiological parameters of distinct phytoplankton communities are expected to vary between surface and the DCM, but not predictably across a range of trophic status.

Xx poniewaz czerwone komorki sa miejsze, wskazuje to, ze mniejsze komorki moga miec lepsze JVPSII. Elektron transport. Moze to bc zwiazane z szybszym metabolizmem. Jednak, w najwyzszym swietle notowano inhibicje wzrostu, nawet, gdy transprt elektronow byl bardzo wysoki. Swiedczy to otym, ze zielone szczepy PC lepiej sobie radza w wysokim swietle, natomiast PE w niskim.

For a given oceanographic process that provide a gradient of nutrient supply, and therefore, a gradient of trophic status composed of different phytoplankton communities (see discussion in Ciotti et al. 1999), we hypothesized that observed values of Fv/Fm and σPSII will resemble that presented by Suggett et al. (2009), with Fv/Fm increasing from oligotrophic to eutrophic areas, while σPSII decreases, as communities will change dominance from small to larger cells. These gradient of cell size is expected to alter the efficiency for light absorption as well (Ciotti et al. 2002), which will tend to decrease with increasing cell size. Ciotti et al. (in preparation) have shown that the variability observed in pigment packaging at the surface is much higher than that observed in the DCM across large trophic gradients in the Atlantic and Pacific.

We hypothesize that the use of pigments ratios would significantly improve the description and interpretation of Fv/Fm and σPSII across different oceanographic regimes as these ratios represent not only biomass and taxonomy, but also the interactions among taxonomy and acclimation processes, which will reflect in the bulk signal of the community photo-physiology.

The studies above have discussed the influence of environmental variables and phytoplankton community structure in Fv/Fm and σPSII. These parameters, especially Fv/Fm, have historically described physiological stress driven by nutrient limitation (Cleveland and Perry 1987; Kolber et al. 1988; Geider et al. 1993, Behrenfeld 2006), however, other studies showed that natural communities are able to acclimate to nutrients-limitation conditions (Parkhill et al. 2001) making the response of photo- physiology more significantly related to phytoplankton taxonomy and dominant cell size (Moore et al. 2008, Suggett et al. 2009; Chapter 3 - now published as Giannini and Ciotti 2016), that at first order varies according with the dynamics of a given environment (Cullen et al. 2002). Although phytoplankton community structure is expected to drive the variability of both Fv/Fm and σPSII, and also the relationship between each other at least for eukaryotes, the data of the present work show no consistency across large-scale oceanographic regions.

Rola carotenoidow

Moze carotenoidy sa wazne? Rozna ilosc w roznych piko

The authors found unexpected relationships between Fv/Fm and the fractional contribution of some individual diagnostic pigments, such as and Zeaxanthin. The present study was conducted also in the mid-austral summer along the 35°S and subtropical gyre, and the results showed robust relationships among photo-physiological parameters (Fv/Fm and σPSII) and a series of individual pigments ratios.

The comparison between the three zonal sectors in the present study reveals a greater influence of individual photo-protective carotenoids in the variability of Fv/Fm at the 35°S latitude, while the relationship with the PPC index was not significant in this sector.

The physical processes along this sector promote vertical instabilities driven by eddies, which may bring nutrients to the euphotic zone but expose the phytoplankton community to higher light levels, explaining the importance of some photo-protective pigments in Fv/Fm.

As far as we know there is no specific studies about the differences in the photochemical efficiency of PSII and the effective cross-section of light absorption for distinct ecotypes in natural environments, for Synechococcus, and it is reasonable to suggest that different ecotypes or genotypes might have contrasting photosynthetic performances across large spatial scale in the global oceans, being a subject that deserves further studies.

Sig vs pig ratio

The relationships discussed here aim to identify trends between pigment ratios and photo-physiology in order to assess the impacts of phytoplankton communities and photo-acclimation processes simultaneously on photosynthetic and absorption efficiencies at different large scale oceanographic regions. Although the chosen linear correlations resulted in low coefficients of determination, the existence of significant correlations are considered important results for construct predictive models.

As phytoplankton pigments composition provides a useful information on taxonomy, but also physiological state and, as shown here, photochemical and light absorption efficiencies, it can be a powerful tool to directly monitor potential primary production in large-scale and improve future parameterizations.