MARINE PHYTOPLANKTON PRIMARY PRODUCTION AND ECOPHYSIOLOGY USING CHLOROPHYLL-*A* FLUORESCENCE

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I declare that this thesis is my own account of my reseach and contains work which has not previously been submitted for a degree in any tertiary institution

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(Jeffrey J. Cosgrove)

ABSTRACT

Marine phytoplankton ecophysiological state and primary production measurements have typically been controversial due to potential impacts of measurement techniques. Advances in chl-*a* fluorescence techniques have provided a means for rapid, non-invasive measurement of electron transport through photosystem 2 (PSII) in dilute phytoplankton suspensions. While studies on higher plants have outlined a close relationship between PSII electron transport and carbon fixation, results from studies on microalgae reveal significant variations in the relationship.

Three species of phytoplankton representing three major taxonomic groups of the marine phytoplankton were used in this study: (1) *Chaetoceros muelleri* CS176 Lemmermann (Bacillariophyta), (2) *Isochrysis galbana* CS177 Parke (Haptophyta) and, (3) *Nannochloropsis oculata* CS179 (Droop) Hibberd (Ochrophyta, eustigmatophyte). Each species was cultured in semicontinuous culture and primary production was estimated using oxygen evolution and carbon fixation techniques and compared against predictions based on chl-*a* fluorescence measurements. It was found that predicted values of primary production both under-estimated and over-estimated actual carbon fixation measured via radioisotope (^{14}C) techniques. This variation was primarily explained by probable errors in the assumed values for PSII density. The relationship between oxygen evolution or carbon fixation with chl-*a* fluorescence-derived measures was commonly linear below the light saturation parameter, with a departure from linearity occurring at higher irradiances. This departure from linearity was greatest in cultures adapted to low light conditions. At higher light intensities alternative electron pathways such as the Mehler reaction

and/or chlororespiration are likely to be more active in low light-adapted cultures, leading to this greater non-linearity.

Chl-*a* fluorescence measurements were also found to be a useful in characterising ecophysiology using photosynthesis-versus irradiance curves. However, an important caveat on this is the measurement of PSII density (η_{PSII}) rather than use of an assumed value as changes in η_{PSII} can have a profound impact on light curve parameters.

A field study in Fremantle Harbour found a healthy (negligible nutrient starvation), diatom dominated, phytoplankton community. Results suggest that phytoplankton are able to begin boosting photosynthetic capability just prior to morning twilight. Waters in the harbour were well mixed via tidal motion and substantial midday photoinhibition was not observed. Data suggest levels of primary production at the mouth of the harbour are similar to those of coastal waters in the plume of the Ocean Reef wastewater outfall.

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Abbreviations

Please note that:

- Chl-*a* fluorescence parameters are defined in Table 1.1 (pg. 45)
- Biophysical parameters are defined in Table 1.3 (pg. 65)

A	Absorptance
ASC	Ascorbate
CET	Cyclic Electron Transport
DCMU	3-(3,4-dichlorophenyl)-1,1-dimethylurea
$\Delta\mu_{H+}$	Transthylakoid electrochemical gradient
$\Delta\Psi$	Electrical component of $\Delta\mu_{H+}$
ΔpH	Transthylakoid proton gradient (chemical component of $\Delta\mu_{H+}$)
E	Irradiance (W m^{-2})
E_{PAR}	Photosynthetically Active Radiation (400 – 700 nm, μmol quanta m^{-2} s^{-1})
E_{PSII}	Photosynthetically Active Radiation available for charge separation at PSII (350 – 400 nm, μmol quanta m^{-2} s^{-1})
E_k	Saturation irradiance (350 – 400 nm, μmol quanta m^{-2} s^{-1})
ED unit	Emittor-Detector unit (component of the Water-PAM fluorometer)
ETC	Electron Transport Chain
ETR	Electron Transport Rate (μmol electrons [mg chl-*a*]$^{-1}$ s^{-1})
ETR_{max}	Maximum Electron Transport Rate (μmol e^- [mg chl-*a*]$^{-1}$ s^{-1})
rETR	Relative Electron Transport Rate (relative units)
$rETR_{max}$	Maximum Relative Electron Transport Rate (relative units)
Φ_{CO2}	Quantum yield of carbon fixation
Φ_{O2}	Quantum yield of oxygen evolution
Φ_{PSII}	Quantum yield of electron transport through PSII
f_{II}	Fraction of absorbed radiation directed to PSII
Fd	Ferredoxin

FNR	Ferredoxin-$NADP^+$ reductase
FQR	Ferredoxin-(plasto)quinone reductase
FR	Far-red (light)
FRR	Fast Repetition Rate
Γ_{O2}	Stoichiometric ratio of O_2 evolved per electron generated at PSII
GOE_f	Gross O_2-evolution predicted from chl fluorescence measurements (μmol O_2 m^{-2} s^{-1})
GOE_f^{chl}	Chl-specific gross O_2-evolution predicted from chl fluorescence measurements (μmol O_2 (μg chl-*a*)$^{-1}$ h^{-1})
HL	High Light
LC	Light Curve
LC(3)	Light Curve with 3 min at each irradiance
LC(20)	Light Curve with 20 min at each irradiance
LED	Light-Emitting Diode
LHCI	Light Harvesting Centre (antennae) of PSI
LHCII	Light Harvesting Centre (antennae) of PSII
LL	Low Light
MAP	Mehler Ascorbate Peroxidase
MDA	Monodehydroascorbate
MDAR	Monodehydroascorbate Reductase
ndh	NAD(P)H-dehydrogenase
NIFT	Nutrient Induced Fluorescence Transient
NPQ	Non-photochemical Quenching
NPQ_{max}	Maximum Non-photochemical Quenching
OEC	Oxygen Evolving Complex (attached to PSII)
P^{chl}	Chl-specific rate of primary production (μmol C (μg chl-*a*)$^{-1}$ h^{-1})
P_f^{chl}	Chl-specific rate of primary production predicted from chl fluorescence measurements (μmol C (μg chl-*a*)$^{-1}$ h^{-1})
P_{O2}	Photosynthetic rate derived from O_2-evolution measurements (μmol O_2 m^{-2} s^{-1})
$P^{chl}{}_{O2}$	Chl-specific photosynthetic rate derived from O_2-evolution measurements (μmol O_2 (μg chl-*a*)$^{-1}$ h^{-1})

PAM	Pulse Amplitude Modulated
PCOC	Photorespiratory Carbon Oxidation Cycle
Ph	Pheophytin
PPFD	Photosynthetic Photon Flux Density (μmol quanta m^{-2} s^{-1})
PQ	Plastoquinone
PQH_2	Plastoquinol
PSI	Photosystem I
PSII	Photosystem II
PSU	Photosynthetic Unit
PSU_{O2}	Photosynthetic Unit size of oxygen production
PTOX	Plastid Terminal Oxidase
q_E	Energy dependent component of NPQ
q_I	Photoinhibition component of NPQ
q_P	Photochemical quenching
q_T	State-transition component of NPQ
Q_{phar}	Absorbed photosynthetically usable radiation (μmol quanta m^{-2} s^{-1})
QR_{O2}	Quantum requirement for oxygen evolution
RCII	Photosystem II Reaction Centre (also known as P_{680})
RLC	Rapid Light Curve
Rubisco	Ribulose-1,5-bisphosphate carboxylase oxygenase
SOD	Superoxide Dismutase