PHOTOSYNTHETIC PERFORMANCE AND PRODUCTIVITY OF PHYTOPLANKTON IN THE SOUTHERN OCEAN

by

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I declare that this thesis contains no material which has been accepted for a degree or diploma by the University or any other institution, except by way of background information and duly acknowledged in the thesis, and that, to the best of my knowledge and belief, this thesis contains no material previously published or written by another person, except where due acknowledgement is made in the text of the thesis, nor does the thesis contains any material that infringes copyright.

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Abstract

Marine phytoplankton account for approximately half of global primary production, an amount equivalent to their terrestrial counterpart. These short-lived organisms, with turnover rates between one and three weeks, support nearly all life in the ocean and have a profound effect on global biogeochemical cycles and climate. The connection between marine phytoplankton and climate is intimate and changes to either will profoundly affect the other. Over the years, due to high operational costs and distance from major human settlements, the Southern Ocean has been the least studied ocean, despite its significance in the distribution of nutrients to the world oceans, especially the lower latitudes, and controlling global climate. In order to capture the response of the phytoplankton to environmental change across the vast Southern Ocean, a method with high spatio-temporal resolution is desirable. By focusing on the Australian sector of the Southern Ocean, this dissertation examines the productivity and physiology of natural phytoplankton communities *in situ* using the fast repetition rate (FRR) fluorometry technique.

The FRR fluorometry technique was used to derive direct estimation of *in situ* primary productivity in the Southern Ocean during the SAZ-Sense (Sub-Antarctic Zone Sensitivity to Environmental Change) voyage in Jan-Feb 2007. A statistically significant correlation between FRR- and ^{14}C-derived primary production was observed ($r^2 = 0.85$, slope $= 1.23 \pm 0.05$, $p < 0.01$, $n = 85$) but the relationship between the methods differed vertically and spatially, mainly due to the effect of non-photochemical quenching under high irradiance. This indicates the FRR fluorometry technique can be used to determine *in situ* primary productivity in the Southern Ocean but care should be taken in the interpretation of the data.

In addition to the primary production measurements, the photosynthetic performance of phytoplankton was investigated to provide a better understanding of how natural phytoplankton communities acclimate to different environmental variables, especially in the iron-replete Subantarctic Zone (SAZ) and iron-depleted Polar Frontal Zone (PFZ). High effective

photochemical efficiency of photosystem II ($F'_q/F'_m > 0.4$), maximum photosynthesis rate (P^B_{max}), light-saturation intensity (E_k), maximum rate of photosynthetic electron transport ($1/\tau_{PSII}$), and low photoprotective pigment concentrations observed in the SAZ correspond to high chlorophyll *a* and iron concentrations. In contrast, phytoplankton in the PFZ exhibits low F'_q/F'_m (~ 0.2) and high concentrations of photoprotective pigments under low light environment. Strong negative relationships between iron, temperature, and photoprotective pigments demonstrate that cells were producing more photoproctive pigments under low temperature and iron conditions, and are responsible for the low biomass and low productivity measured in the PFZ.

FRR fluorometry data from 31 transects collected aboard MV I'Astrolabe between 2002 and 2009, were used to assess the photosynthetic performance of phytoplankton along a repeated transect from Hobart (42.8°S, 147.3°E) to the French Antarctic station, Dumont d'Urville (66°S, 140°E). The maximum photochemical efficiency of photosystem II (F_v/F_m) values were high in the Subtropical Zone and water close to the Antarctic continent, but low in the PFZ. Spring F_v/F_m were higher than other seasons, suggesting higher nutrient supply. High F_v/F_m observed in the Subtropical Zone and Antarctic Zone is consistent with moderate to high iron concentrations in these regions. Overall, phytoplankton photophysiology in the Southern Ocean is governed by nutrient distributions, especially iron, which are affected by atmospheric and oceanic physical processes.

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Publications resulting from research completed during candidature

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Statement of Co-Authorship

The following people contributed to the publication of the work undertaken as part of this thesis:

Paper 1/Chapter 2 (*Assessing Sub-Antarctic Zone primary productivity from fast repetition rate fluorometry*):

- **Wee Cheah** (81%)
- Andrew McMinn (6%)
- F. Brian Griffiths (4%)
- Karen J. Westwood (3%)
- Simon W. Wright (3%)
- Ernesto Molina (1%)
- Jason P. Webb (1%)
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Paper 2/Chapter 3 (*Dynamic influences of iron and temperature on phytoplankton photophysiology in the changing Sub-Antarctic Zone*):

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Paper 3/Chapter 4 (*Seasonal to interannual variability in phytoplankton photosynthetic performance in the Southern Ocean, 2002-2009*):

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Details of the authors' roles:

Wee Cheah designed and implemented the experiment, performed data analysis and manuscript writing.

Andrew McMinn contributed with project development and refinement, technical and conceptual discussion, and document preparation.

Brian Griffiths and Peter Strutton assisted with technical and conceptual aspects of the papers, as well as document preparation.

Karen Westwood, Simon Wright, and Lesley Clementson provided data and assisted in document preparation.

Ernesto Molina, Jason Webb, and Rick van den Enden provided assistance in data collection.

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