THE DIRECT IMPLICATIONS OF WARMING ON THE PHENOTYPE AND UNDERLYING FUNCTIONAL TRAITS OF MARINE PHYTOPLANKTON

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CERTIFICATE OF AUTHORSHIP/ORIGINALITY

This thesis is the result of a research candidature conducted jointly with another University as part of a collaborative Doctoral degree. I certify that the work in this thesis has not previously been submitted for a degree nor has it been submitted as part of requirements for a degree except as part of the collaborative doctoral degree and/or fully acknowledged within the text.

I also certify that the thesis has been written by me. Any help that I have received in my research work and the preparation of the thesis itself has been acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

Kirralee G. Baker

This thesis is dedicated to my everlasting satellites RB and PB, who always guide me and initially inspired me to discover the natural world, and DR who since joining my path, has filled my life with overwhelming happiness, love and adventure.

ACKNOWLEDGEMENTS

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Thank you to Assoc. Prof. Justin Seymour, Drs Allison McInnes and Christian Evenhuis, and Dale Radford, Charlotte Robinson, Lauren Messer and Marco Alvarez Rodriguez who have provided support in the form of thoughtful discussions, data collection, analysis and methodologies that have allowed this thesis to come to fruition. Your individual contributions are acknowledged within this thesis.

Throughout this research I have been in receipt of financial support from a number of sources and would like to thank the Australian Government for their provision of an APA scholarship, and the School of Life Sciences and C3 Cluster for providing research funding.

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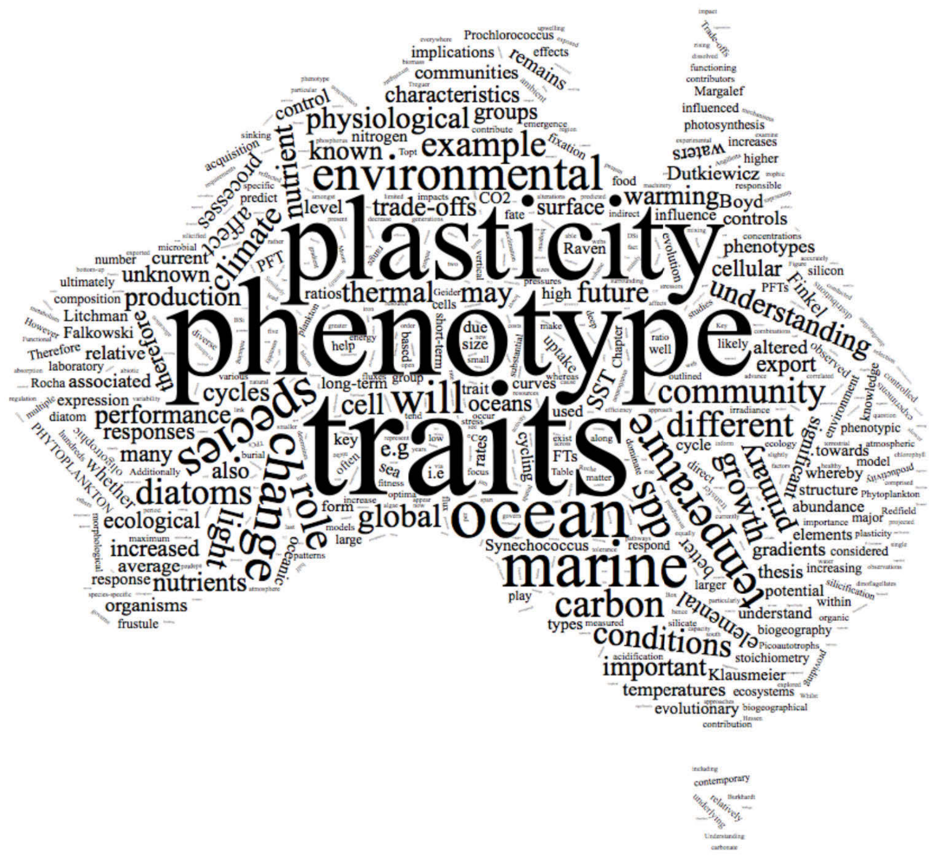
SUMMARY

Marine phytoplankton mediate oceanic biogeochemical cycling by linking cellular metabolism with many elemental fluxes including C, N, P and Si. These elemental transformations are physiologically regulated processes that are influenced by phytoplankton phenotypes that change over different spatial and temporal scales. It is expected ocean warming (increasing sea surface temperatures; SST) will alter these patterns because temperature is the primary environmental control governing metabolism and growth in many phytoplankton groups. Whilst research on the effects of warming SST on biogeographical range shifts is advancing, it remains unknown how phytoplankton mediated biogeochemical transformations may be altered.

Focusing on patterns in species functional traits (FTs), this thesis applied trait-based approaches in laboratory and field studies to explore how biogeochemically-related FTs vary over environmental gradients. I quantified the thermal performance curves (TPCs) of FTs in representative species from two laboratory-cultured phytoplankton functional types to understand trade-offs associated with thermal acclimation and adaptation. To assess whether these laboratory-based patterns of FT trade-offs and expression were consistent in the field; I replicated a similar TPC experiment with a natural phytoplankton community. Finally, to understand how multiple environmental gradients interact to influence phytoplankton FT expression, I tracked a diatom-specific FT over northern Australia to spatially map the diatom phenotypes present to deduce the likely biogeochemical roles of the species in the region.

This thesis demonstrates the importance of understanding the relationship between the duration of thermal exposure, FT expression and trade-offs in regulating the phytoplankton phenotype, as all of these factors differentially affect species' growth rates (and therefore fitness and biogeography) but also the acquisition of C, N, P and Si, and therefore the marine cycling of these elements. Furthermore, ocean mapping of FTs proves insightful for understanding variability of biogeochemical transformations between different ocean regions by providing a link between cellular and community level processes.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DECLARATION OF THE CONTRIBUTION TO EACH CHAPTER

Chapter 2

This chapter has been published in Frontiers in Marine Science. The publication is titled "Thermal performance curves of functional traits aid understanding of thermally induced changes in diatom-mediated biogeochemical fluxes", and the authors are; Kirralee G. Baker, Charlotte, M. Robinson, Dale T. Radford, Allison S. McInnes, Christian Evenhuis, and Martina A. Doblin. I was responsible for conception of the experiment, methodological development, data interpretation and write-up of the manuscript. I was responsible for 2-(4-pyridyl)-5-((4-(2-dimethylaminoethylaminocarbamoyl)methoxy)phenyl)oxazole (PDMPO) assays, growth and cell size data. Dr. Allison McInnes (UTS) and myself conducted flow cytometry analyses. Assoc. Prof. Martina Doblin (UTS) conducted the primary productivity assays and Charlotte Robinson (UTS) collected photophysiology data. I was mostly responsible for post-processing of samples, with assistance in nutrient analysis from Dale Radford (UTS). I was mainly responsible for data analysis, with assistance in bootstrapping of data from Dr. Christian Evenhuis (UTS).

Chapter 3

The data presented in this chapter was a joint laboratory effort. I was responsible for conception of the experiment, methodological development, data analysis and interpretation, and write-up of the manuscript. Biogenic silicon production and PDMPO assays were conducted by myself. Source water collection and characterisation (primary productivity and pigment analyses) were conducted by Marco Alvarez-Rodrigues (UTS). Dr. Allison McInnes (UTS) and myself conducted flow cytometry analyses. Assoc. Prof. Martina Doblin (UTS) conducted the primary productivity assays and Charlotte Robinson (UTS) collected photophysiology data.

Chapter 4

The majority of the data presented in this chapter was collected by myself during the SS2013-t03 voyage in northern Australia (RV Southern Surveyor, July-August 2013). Assoc. Prof. Martina Doblin (UTS), Assoc. Prof. Justin Seymour (UTS), Lauren Messer (UTS) and Charlotte Robinson (UTS) were key contributors securing ship time for this voyage. I was responsible for conception of the experimental design, methodology development, data analysis and interpretation, and write-up of the manuscript. Biogenic silicon production, PDMPO and nitrate addition assays were conducted by myself. I also collected the particulate organic matter and phytoplankton pigment samples, these samples were processed by Lauren Messer (UTS) and Charlotte Robinson (UTS). Dr. Daniel Nielson (UTS) and Dale Radford assisted with image analysis and Dr. Penelope Ajani assisted with phytoplankton identification.

Chapter 5

The data presented in this chapter was a joint laboratory effort. I was responsible for conception of the experimental design, methodological development, data interpretation, and write-up of the manuscript. I was responsible for the collection of the growth, cell size, photophysiological data. Dale Radford (UTS) assisted with nutrient analyses and I assisted Dr. Unnikrishnan Kuzhiumparambil (UTS) with fatty-acid methyl esters (FAME) analysis. I was mostly responsible for data analysis, with assistance in bootstrapping of data from Dr. Christian Evenhuis (UTS). Assoc. Prof. Martina Doblin (UTS) conducted the primary productivity assays and Lisa Hou (UTS) initially established the laboratory cultures used for this experiment.