Growth dynamics and drivers of deep-water seagrasses from the Great Barrier Reef lagoon

Thesis submitted by
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CERTIFICATE OF ORIGINAL AUTHORSHIP

I, Kathryn M. Chartrand declare that this thesis, is submitted in fulfilment of the requirements for the award of Doctor of Philosophy, in the Faculty of Science at the University of Technology Sydney.

This thesis is wholly my own work unless otherwise referenced or acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

This document has not been submitted for qualifications at any other academic institution.

This research is supported by the Australian Government Research Training Program.

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Signature removed prior to publication.

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PREFACE

This thesis is written in the format of a thesis by compilation— a combination of published chapters and those unpublished but with the intention of publication in a peer-reviewed scientific journal in the near future. Citations and references have been formatted throughout using the style applied by the peer-reviewed journal *Frontiers of Marine Science*. Given that this thesis is presented as a series of ready to submit manuscripts, there is an element of repetition in the introduction of some chapters since they are each submitted as stand-alone manuscripts. At the time of thesis submission, Chapter 3 has been published in the peer-reviewed *Marine Environmental Research* (IF 2.73). Chapter 2 has been submitted to *Limnology and Oceanography* (IF 3.78), Chapter 4 to *Estuaries and Coasts* (IF 2.42) and Chapter 5 is being prepared for submission to *Frontiers of Marine Science* (IF 3.07).

Supervisory committee

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STATEMENT OF CONTRIBUTION OF OTHERS

CHAPTER 2

Authors: Chartrand K.M., Bryant C.V., Ralph P.J., and Rasheed M.A.

KC and MR conceived the study and designed the sampling strategy. KC led and designed field data collection with CB leading field logistics and data collection during

KC's maternity leave. KC analysed the data, prepared all figures and tables, and wrote the draft manuscript. MR and PR supervised the study. All authors provided valuable feedback on the draft manuscript and contributed valuable insights in the discussion.

CHAPTER 3

Authors: Chartrand K.M., Szabó M., Sinutok S., Rasheed M.A., and Ralph P.J.

KC, MR and PR conceived the study and KC, MS, SS and PR designed the methodological approach and sampling strategy. KC led the collection and shipment of seagrass from Queensland to UTS for laboratory studies. SS maintained samples and performed weekly checks on samples in the laboratory while KC was based remotely in Cairns. KC conducted the laboratory studies with technical support from MS and SS. MS provided valuable contributions to data quality control measures and provided regular supervision through the data collection, analysis and interpretation. SS assisted with the use of oxygen optodes for oxygen determinations and fluorometric measurements. KC analysed the data, drafted the manuscript, prepared figures and tables and arranged the submission and approval for publication. MS and PR contributed to the intellectual content of the manuscript. PR supervised the study.

CHAPTER 4

Authors: Chartrand K.M., Bryant C.V., Ralph P.J., and Rasheed M.A.

KC and MR conceived the study and designed the sampling strategy. KC led and designed field data collection with CB leading field logistics and data collection during KC's maternity leave. KC analysed the data, prepared all figures and tables, and wrote

the draft manuscript. MR and PR supervised the study. All authors provided valuable feedback on the draft manuscript and contributed valuable insights in the discussion.

CHAPTER 5

Authors: Chartrand K.M., Kuzhiumparambil U., Pernice M., Ralph P.J.

KC, MP, and PR conceived the study. KC led the collection and shipment of seagrass samples from Queensland to UTS. KC organized laboratory standards for hormone analysis and worked alongside UK to extract hormones and prepare metabolome samples. UK ran all samples through mass spectrometry instrumentation. PR, UK, and MP provided advice and constructive feedback on test results and analysis and UK provided guidance on interpretation of the results. All authors contributed valuable feedback on the draft manuscript and contributed valuable insights in the discussion.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABSTRACT

Seagrasses provide irreplaceable ecosystem services, yet in the Anthropocene, they are increasingly under threat from coastal development and climate impacts. Efforts to mitigate threats to seagrasses have led to investment and research into their distribution, ecological drivers and bioindicators of health. In the Great Barrier Reef (GBR), work continues to translate our mechanistic understanding of marine plants into impactful management of acute disturbances and chronic stressors. These applied outcomes have primarily focused on shallow seagrass communities, synthesising results and deriving relationships to be used by managers and regulators.

The goal of this thesis is to build our understanding of the dynamics and underlying drivers of GBR deep-water seagrasses for their better management and the communities they support. To achieve this, I (i) studied the seasonal patterns of deep-water seagrasses, characterising environmental parameters linked with growth and senescence; (ii) evaluated light and temperature as drivers of seagrass abundance and determined light thresholds for the dominant *Halophila* species; (iii) quantified seed banks over time and space, evaluating the role of seed stratification on germination; and (iv) investigated what role endogenous cues play in the phenology of a *Halophila* species.

Deep-water *Halophila* species did not all follow the same growth patterns. Only *Halophila decipiens* had a true annual pattern, completing its life cycle in one growing season and depositing seeds for the subsequent year's renewal. Deep-water GBR seagrasses grow near their physiological limits with small light reductions potentially

leading to meadow-scale loss, and yet their physiological limits also vary among species. Limiting light led to decreased shoot density for both *H. decipiens* and *H. spinulosa* over different timeframes, yet neither were affected by increases in temperature irrespective of compounding low light stress. Variations in meadow reproductive output and seed banks critically structure deep-water meadows and underscore species-specific responses to environmental perturbations. Endogenous cues responsible for life stage transitions in terrestrial plants had not been studied before in seagrasses. The metabolomic profile, including key hormones, within the life stages of the *H. decipiens* growing cycle provided the first study linking metabolomic regulation with seagrass growth and development and underpins the ecological findings in this thesis.

This thesis contributes critical information on growth strategies that drive spatial and seasonal dynamics of tropical deep-water *Halophila* communities. It provides new insights and a gateway to explore emerging lines of research including greater use of 'omics' technology and integrating terrestrial plant research to further improve deep-water seagrass management.