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**Physiological models of performance
for scleractinian corals**

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September 2008

For the degree of Doctor of Philosophy
in the School of Marine and Tropical Biology
James Cook University

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ACKNOWLEDGEMENTS

First and foremost, I'd like to express my sincere appreciation to my supervisors, Professor Sean Connolly and Dr. Ken Anthony, for the education, mentoring and encouragement they have given me during my PhD candidature. In particular, I want to thank Sean for always having an open door, for always having answers close at hand, and for encouraging me to take that extra step. I want to thank Ken for sharing his in-depth knowledge of coral physiology and energy budgets with me, and for passing on (some of!) his practical and experimental skills.

A number of people gave up their own time to provide me with priceless assistance with field and experimental work. I particularly want to thank Chris Glasson, Erin Graham and Jenni Donelson for helping me out on several occasions at One Tree and Orpheus Islands. Thanks also to Marie Magnusson, Maria Dornelas, David Abrego, Becky Fox, Kerry Johns, James Kealey, Blanche Danastas, Jessica Cox, Fiona Merida, Allison Paley and Naomi Gardiner for help with fieldwork.

A heartfelt thankyou goes to the staff at Orpheus Island Research Station and One Tree Island Research Station who make these stations such fantastic places to work. In particular, I want to thank Konrad and Pam Beinssen for sharing some of their vast knowledge of the One Tree Island ecosystem. Thanks also to Russell, Jenny, Anna and Olli for always being able to solve problems, and always making every effort to make fieldwork as safe and easy as possible. In addition, I'd like to thank the staff at JCU's Marine Aquaculture Research Facility for running an excellent saltwater aquarium facility right in the middle of campus.

I would like to thank all of the people who provided technical support for this work. Thanks to Rob Gegg for giving me the run of the workshop, and to Glen Ewels, Kurt Arrowsmith and Greg Reeves for building various parts for my

respirometry chambers. I would also like to thank Claudia and Greg for various equipment loans, and Bette Willis for letting me take up so much space in her lab. Finally, thanks to Wayne Mallet and the staff of JCU's High Performance Computing team for providing an excellent platform.

I am very grateful to all of the people who have been members of the Theoretical Ecology Lab over the years. Thankyou to Maria, Ailsa, Matt, Loic and Andrew for their honest and constructive feedback on all aspects of my research. Also, thanks to Maria for being the best office-mate ever!

To my partner Duncan, thank you for your tireless support and encouragement, and for being there for me through the ups and downs of my project. Finally, to Mum and Dad, thank you for always believing in me, and for giving me every opportunity to reach my goals.

TABLE OF CONTENTS

Abstract.....	1
1. General Introduction.....	3
1.1. Energetics and the niche.....	6
1.2. Performance of corals: Variation within and between species.....	7
1.2.1. <i>Colony growth</i>	8
1.2.2. <i>Tissue composition</i>	8
1.2.3. <i>Reproductive output</i>	11
1.3. Environmental variation on coral reefs.....	11
1.4. Influence of light and flow on coral energetics.....	14
1.5. Colony morphology and performance.....	18
1.6. Thesis overview.....	19
1.7. Publication details.....	21
2. Energetic costs of photoinhibition at diurnal timescales.....	22
2.1. Summary.....	22
2.2. Introduction.....	23
2.3. Materials and methods.....	26
2.3.1. <i>Experimental setting</i>	27
2.3.2. <i>Chlorophyll concentration</i>	29
2.3.3. <i>Data analysis</i>	30
2.4. Results.....	32
2.4.1. <i>Net photosynthesis and rETR</i>	32
2.4.2. <i>Cost of photoinhibition</i>	37
2.4.3. <i>Fluorescence versus respirometry</i>	41
2.5. Discussion.....	43
2.6. Conclusions.....	48
3. Effects of photo acclimation on niche width of corals: a process-based approach.....	49
3.1. Summary.....	49
3.2. Introduction.....	50
3.3. Materials and methods.....	52
3.3.1. <i>Modelling framework</i>	52
3.3.2. <i>Data sources for model calibration</i>	54
3.3.3. <i>Data collection</i>	55
3.3.4. <i>Relationship between model parameters and growth irradiance</i>	57
3.3.4.1. <i>Oxygen quantum yield</i>	57
3.3.4.2. <i>Light absorption</i>	58

3.3.4.3. Turnover time.....	58
3.3.4.4. Chlorophyll concentration.....	59
3.3.4.5. Absorption cross-section and PSU size.....	60
3.3.4.6. Dark respiration.....	60
3.3.5. Daily energy acquisition.....	60
3.4. Results.....	62
3.4.1. Daily energy acquisition and the light niche.....	66
3.5. Discussion.....	69
3.6. Conclusions.....	75
4. Energetic implications of phenotypic plasticity in foliose corals..	76
4.1. Summary.....	76
4.2. Introduction.....	77
4.3. Model formulation.....	81
4.3.1. Study species.....	81
4.3.2. Colony geometry.....	81
4.3.3. Photosynthesis model.....	83
4.3.4. Light model.....	84
4.3.5. Model analysis.....	89
4.4. Materials and methods.....	91
4.5. Results.....	92
4.6. Discussion.....	96
4.6.1. Alternative explanations for morphological variation.....	97
4.6.2. Accuracy of model predictions.....	99
4.7. Conclusions.....	101
5. Defining fundamental niche dimensions for corals: synergistic effects of colony size, light and flow.....	102
5.1. Summary.....	102
5.2. Introduction.....	103
5.3. Materials and methods.....	106
5.3.1. Modelling framework.....	106
5.3.2. Study species and aquarium set-up.....	112
5.3.3. Water flow and photosynthesis experiments.....	113
5.3.4. Parameter estimation and statistical analyses.....	115
5.3.5. Tissue quality and reproductive output.....	116
5.4. Results.....	119
5.4.1. Mass flux relationships.....	119
5.4.2. Diffusion limitation of photosynthesis and respiration.....	119
5.4.3. Tissue quality and reproductive output.....	122
5.4.4. Niche width: Energy acquisition.....	124

5.5. Discussion.....	130
5.5.1. <i>Mass flux model</i>	131
5.5.2. <i>Predictive accuracy of the niche model</i>	132
5.5.3. <i>Effect of colony size on predicted niche dimensions</i>	133
5.6. Conclusions.....	134
6. General Discussion.....	135
6.1. Summary of results.....	135
6.2. Robustness of results.....	139
6.2.1. <i>Heterotrophy</i>	139
6.2.2. <i>Carbon excretion</i>	143
6.2.3. <i>Nutrient limitation</i>	145
6.3. Directions for future research.....	147
6.4. Conclusions and implications.....	148
References.....	149
Appendix A.....	182
Appendix B.....	183
Appendix C.....	207
Appendix D.....	208
Appendix E.....	210

LIST OF FIGURES

Chapter 1

- Figure 1.1:** Environmental conditions and distribution of coral genera across reefs..... 4
- Figure 1.2:** Tissue composition of scleractinian corals..... 10

Chapter 2

- Figure 2.1:** Diurnal photosynthesis and electron transport versus irradiance for corals acclimated to three light regimes..... 33
- Figure 2.2:** Variation in average parameter values of photosynthesis versus irradiance curves between morning and afternoon..... 35
- Figure 2.3:** Percentage difference in net and gross photosynthesis over the morning compared with the afternoon..... 38
- Figure 2.4:** Daily integrated photosynthetic oxygen evolution for corals acclimated to three light regimes and exposed to two diurnal irradiance cycles..... 40
- Figure 2.5:** Relationships between photosynthetic activity measured by oxygen respirometry versus fluorescence..... 42

Chapter 3

- Figure 3.1:** Effects of growth irradiance on photosynthesis properties of *Turbinaria mesenterina*..... 62
- Figure 3.2:** Effects of growth irradiance on chlorophyll concentration and rate of dark respiration for *Turbinaria mesenterina*..... 64
- Figure 3.3:** Tradeoffs between different properties of photosynthesis..... 65
- Figure 3.4:** Dimensions of the light niche for *Turbinaria mesenterina*..... 66
- Figure 3.5:** Sensitivity of niche boundaries to each parameter that describes photoacclimation to growth irradiance for *Turbinaria mesenterina*. 67

Chapter 4

- Figure 4.1:** Variation in colony morphology with depth for *Turbinaria mesenterina* at Nelly Bay..... 82
- Figure 4.2:** Geometric rendition of model colonies..... 83
- Figure 4.3:** Curvilinear relationship between scattered and total irradiance..... 92
- Figure 4.4:** Variation in parameters of photosynthesis versus irradiance relationship for colonies of *Turbinaria mesenterina* acclimated to different light regimes..... 94
- Figure 4.5:** Comparison of observed variation in colony morphology along a depth gradient with predicted optimal colony morphologies..... 95
-

Chapter 5

Figure 5.1: Map of One Tree Island study sites.....	117
Figure 5.2: Sherwood versus Reynolds relationship for colonies of <i>Acropora nasuta</i> , <i>Leptoria phrygia</i> and <i>Montipora foliosa</i> acclimated to high and low light levels.....	120
Figure 5.3: Tissue surface oxygen concentration for <i>Acropora nasuta</i> , <i>Leptoria phrygia</i> and <i>Montipora foliosa</i> during photosynthesis and respiration.....	121
Figure 5.4: Correlations between predicted energy acquisition with reproductive output and tissue biomass for <i>Acropora nasuta</i> , <i>Leptoria phrygia</i> and <i>Montipora foliosa</i>	123
Figure 5.5: Niche dimensions for 10 and 40 diameter colonies of three species along gradients of light intensity and flow velocity.....	125
Figure 5.6: Simulated niche dimensions for colonies of three species acclimated to different light levels.....	129

LIST OF TABLES

Chapter 1

Table 1.1:	Growth rates of scleractinian corals.....	9
Table 1.2:	Reproductive output of scleractinian corals.....	12
Table 1.3:	Summary of literature estimates of daily carbon acquisition from symbiont photosynthesis for scleractinian corals.....	17

Chapter 2

Table 2.1:	Analysis of Variance for the effect of photoacclimatory state, diurnal irradiance cycle and time of day on photosynthesis-irradiance curve parameters.....	36
Table 2.2:	Comparison of the proportional difference between integrated net and gross photosynthesis over the course of the afternoon versus the morning.....	39
Table 2.3:	Change in photosynthetic properties of corals acclimated to low light following repeated exposure to excessive irradiance.....	39

Chapter 3

Table 3.1:	Modelled dependence of photosynthesis parameters on growth irradiance: summary of functional forms and parameter estimates	59
Table 3.2:	Sensitivity of the relationships between PSU size and absorption cross-section with growth irradiance due to variation in the values of k and % light absorption.....	68

Chapter 4

Table 4.1:	Phenotypically plastic corals: extent of morphological variation and environmental cue.....	79
Table 4.2:	Summary of parameters and equations together with best-fit parameter estimates for light and photosynthesis models.....	86

Chapter 5

Table 5.1:	Definitions of mass-transport and photosynthesis model parameters.....	109
Table 5.2:	Best-fit parameter estimates of equation describing variation in tissue oxygen concentration with increasing Reynolds number during photosynthesis and respiration.....	122
Table 5.3:	Parameter values describing the relationship between Reynolds number and tissue oxygen concentrations for simulated photoacclimatory states.....	128

Chapter 6

Table 6.1:	Summary of literature estimates of daily carbon and nitrogen acquisition from various modes of heterotrophic feeding.....	140
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ABSTRACT

A fundamental objective of ecology is to evaluate the conditions that permit different species to survive and reproduce, that is, to identify each species' 'niche'. The overarching aim of this thesis was to identify and quantify the primary processes that influence the distribution and abundance of reef-building, scleractinian corals. My general approach was to develop and calibrate process-based models that link physiology to environmental conditions, and quantify ecological performance as a function of physiology.

Light intensity is a fundamental determinant of coral performance. For several photosynthetic taxa exposure to high light levels causes a decline in daily carbon gain. In this thesis I first investigated whether this phenomenon (i.e. photoinhibition) had energetic consequences for coral symbioses. Surprisingly, results demonstrated that costs of photoinhibition are negligible under short-term exposure to high irradiance (Chapter 2). I subsequently investigated whether costs of photoinhibition manifest over a longer time-period due to changes in the photosynthetic apparatus that arise during photoacclimation to high light intensities (Chapter 3). Analyses revealed that repeated exposure to high light intensity causes changes in the photosynthetic machinery such that high-light habitats do not provide maximal energy acquisition. In fact, I found evidence of a strong reduction in energy available for growth and reproduction for corals growing under high light.

Corals potentially avoid costs of excessive light exposure by altering colony morphology. Previously, no framework has been available that allowed comparison of energy acquisition for multiple, complex coral morphologies, in response to varying light conditions, while taking into account the flexibility in coral photophysiology. Using a novel, three-dimensional geometric model of light capture

in combination with a comprehensive photosynthesis dataset, in Chapter 4 I demonstrate that morphological plasticity maximizes the amount of energy corals have available for growth and reproduction. In addition, results showed that variation in morphology is most important at niche boundaries whereas physiological flexibility is important in intermediate habitats.

In addition to light intensity, water flow velocity varies markedly between reef habitats and has a strong influence on coral metabolism. In this thesis, I built on existing models of gas exchange to incorporate the effects of light intensity, flow velocity and colony size into a single model (Chapter 5). Analysis of this model showed that the branching coral *Acropora nasuta* has a positive energy balance over a wider range of conditions than both a massive (*Leptoria phrygia*) and a foliose species (*Montipora foliosa*). Moreover, colony size was revealed as having a strong influence on niche width: large colonies of all three species had a positive energy balance over a broader range of conditions than small colonies.

The overarching aim of my thesis was to evaluate the performance of corals in response to environmental gradients. This work quantifies the mechanisms through which light and flow influence coral physiology. Model predictions were strongly correlated with observed tissue biomass and reproductive output. In addition, an optimality model based on morphology-specific energy acquisition as a function of the ambient light-regime, adequately captured observed variation in colony shape across a depth gradient. Overall, this thesis provides new insight into the processes underlying the habitat distributions of reef-building corals, achieved by quantifying environmental effects on physiology and integrating these effects into an energy-budget framework.