# Physiological models of performance for scleractinian corals

**Mia Odell Hoogenboom**

September 2008

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

## STATEMENT OF ACCESS

I, the undersigned, the author of this thesis, understand that James Cook University will make this thesis available for use within the University Library and via the Australian Digital Theses network (unless granted any exemption) for use elsewhere.

I understand that, as an unpublished work, a thesis has significant protection under the Copyright Act and;

I wish this work to be embargoed until September 2009.

| | |
|---|---|
| ______________________ | 04-09-2008 |
| Signature | Date |

## ELECTRONIC COPY OF THESIS

I, the undersigned, the author of this work, declare that the electronic copy of this thesis provided to the James Cook University Library is an accurate copy of the print thesis submitted, within the limits of the technology available.

_________________________ 04-09-2008

Signature Date

## STATEMENT OF SOURCES

I declare that this thesis is my own work and has not been submitted in any other form for another degree or diploma at any university or other institution of tertiary education. Information derived from the published or unpublished work of others has been acknowledged in the text and a list of references is given.

___________________________ 04-09-2008

Signature Date

# 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, Kerryn 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

# LIST OF FIGURES

**Chapter 1**



**Chapter 2**



**Chapter 3**



**Chapter 4**

**Chapter 5**

# LIST OF TABLES

# 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.