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**Physiological models of performance
for scleractinian corals**

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

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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.