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TITLE PAGE

Massive *Porites* corals as indicators of environmental changes

Thesis submitted by

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For the degree of Doctor of Philosophy
in the Discipline of Marine Biology
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James Cook University

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Little did I know, when I commenced this PhD, how little I knew about how to go about one. This has been a long and particularly frustrating project, beset by hordes of annoying delays, problems, failures and an almost unending supply of bad luck. That I have finished at last is a tribute to the many people – family, friends, volunteers and scientists – who assisted me throughout the last several years.

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Abstract

Monitoring the responses of corals to environmental change and linking responses to past environmental changes are difficult and rely on correlative proxy techniques. To date, there has been no means to directly measure biologically meaningful effects of environmental changes on corals that could both explain the consequences of sublethal stress and enhance the interpretation of proxy environmental records. Massive *Porites* are extremely widespread in the Indo-Pacific. While not exceptionally fecund, fast-growing or competitively dominant, they appear to possess a peculiar robustness, often becoming the dominant corals on reefs that have been heavily impacted. The longevity of *Porites* colonies and the existence of annual density bands in their skeletons, makes them organism of choice for Indo-Pacific researchers interested in the construction of proxy climate records. This project aimed to address the lack of knowledge about the biological responses of *Porites* to various types of stress and to relate these responses to proxy environmental records derived from the corals' skeletons. In addition, the project sought to develop a measure of sublethal stress which could be adapted into a general reactive monitoring protocol.

The thickness of the tissue layer (TTL) of a colony of *Porites* is a product of linear skeletal extension at its upper surface and periodic (up to monthly) uplift of its lower margin. A survey of 20 reefs on the GBR, as well as several reefs in PNG and the Gulf of Thailand indicated that tissue thickness of massive *Porites* corals varies in space and time. Spatial variation in TTL is mostly a manifestation of local (habitat-level) environmental conditions rather than an indication of broad geographic trends in conditions. Seasonal trends in TTL variation of *Porites* on the central GBR manifest as summer maxima and winter minima, as reported for calcification and linear extension. SST and insolation are the factors most likely to be responsible for seasonal cycles in TTL. TTL variation is a sensitive indicator of incipient or sublethal stress in massive *Porites*. Lack of stress-specific responses precludes distinguishing between chronic and acute stress solely from the thickness of the tissue layer.

Continual mobilization of the lower portion of the tissue layer provides a unique mechanism by which massive *Porites* can control its response to stressful conditions. Moreover, tissue thickness and lipid levels appear to be interchangeable indications of the energy level of the polyp under stress, although extreme responses such as bleaching are more closely linked to tissue thickness than lipid levels. The response of corals to environmental impacts is dictated largely by their available energy reserve. Diminishment of a coral's ability to acquire energy leads to a reduction in linear extension as the coral adapts. Reduction of the coral's somatic reserve past a critical point leads to a bleaching response concomitant with shutdown of other functions.

Mass spectroscopic analysis of skeletal cores taken from colonies used in the long term stress experiment revealed that proxy environmental reconstruction techniques based on isotope ratios within the coral skeleton are able to capture stress events in the life of a coral identified by TTL changes. Changes to the amplitude and range of $\delta^{18}O$ and $\delta^{13}C$ cycles during experimental shading suggest that chronic stress changes the way that corals record environmental variation. The sensitivity of isotopic techniques is diminished, however, by previous stress events. Likewise, interpretation of the nature of the stress event from the proxy record is problematic: proximal environmental variation is not recorded, and non-related stress events can leave identical signatures in the isotope record. Skeletal proxy techniques will therefore underestimate the frequency of environmental impacts. These findings shed light on why it has so far been difficult to reconcile proxy records from different studies.

The use of TTL variation as a simple reactive monitoring technique is not readily achievable. Between-colony, habitat and seasonal variation, as well as the need to contextualize measurements to previous history, all place severe constraints on its utility as a simple technique. However, localized spatial gradients in TTL can identify environmental gradients and map their severity. As such, changes in TTL can be used as a broad-scale tool to identify habitats with sub-optimal or impacted environments.

Table of Contents

List of Figures

List of Figures

List of Tables