

**Physical Conditions on Marginal Coral Reefs**

**Thesis submitted by**

**James Christopher WHINNEY MPhys**

**In March 2007**

**for the degree of Doctor of Philosophy  
in the School of Mathematics, Physics, and Information Technology  
James Cook University**

## STATEMENT OF ACCESS

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

I understand that, as an unpublished work, a thesis has significant protection under the Copyright Act and I do not wish to place any further restriction on access to this work.

\_\_\_\_\_  
Signature

\_\_\_\_\_  
Date

## **STATEMENT OF SOURCES**

### **DECLARATION**

I declare that this thesis is my own work and has not been submitted in any 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 Information derived from the published or unpublished work of others has been acknowledged in the text and a list of references is given.

\_\_\_\_\_  
Signature

\_\_\_\_\_  
Date

## **ELECTRONIC COPY**

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.

\_\_\_\_\_  
Signature

\_\_\_\_\_  
Date

## STATEMENT ON THE CONTRIBUTION OF OTHERS

The contributions of others towards this thesis included knowledgeable discussions, proofreading of manuscripts, and manual help with field work.

Project costs were covered by the supervisor. Fees and stipend support were paid by an International Postgraduate Research Scholarship and by the School of Mathematics, Physics, and Information Technology.

\_\_\_\_\_  
Signature

\_\_\_\_\_  
Date

## **ACKNOWLEDGEMENTS**

I would like to thank my friends and family for their support during my studies, particularly my wife, Zhen. Thank you to all those people who helped me with my field work and with academic advice, especially my supervisor, Peter Ridd, for his expert advice, guidance and support.

# Abstract

The Great Barrier Reef Lagoon (GBRL) is an area of great biodiversity containing 350 species of corals, 10 of which are endemic to the region. In recent years many threats to this ecosystem have been revealed, such as crown-of-thorns starfish and coral bleaching as well as excess concentrations of nutrients and sediments. Information on the effects of water quality and also the amounts of nutrients and sediments that reefs are subjected to is limited. This is especially true for inshore reefs where issues of water quality are most important.

This work focuses on the Rockingham Bay and Family Islands region. In this region a reef in Lugger Bay near Mission Beach was selected for a detailed study. It is a highly marginal reef (a reef occurring close to perceived environmental thresholds for coral survival) with high levels of sediments and organic matter and close to the mouths of two rivers: the Tully and the Hull. This makes the reef one of the most at threat from eutrophication and increases in sediment. Part of this work was to document all the physical conditions of the reef including currents, wind speed and direction, light levels, temperature, nutrients, and suspended sediment concentration (SSC). The reef's health and age were also found by means of photographic surveys and core samples respectively.

The main results from the study showed a reef surviving in extreme physical conditions. The SSC on the reef were very high, exceeding 200 mg/l for 28% of the time. Light extinction was common, occurring on 49% of the days that data was recorded. The local rivers did not have much effect on the SSC or nutrient concentrations on the reef. The Tully River only has a wet-season average SSC of 23 mg/l and a maximum of 230 mg/l; resuspension was much more significant. Coral cover on the reef was reasonable, about 57%, and algae only covered 12% of the coral. However, coral species biodiversity was low, with one species of *Porites* making up 85% of the coral cover. These results indicate that some species of coral are able to survive in areas of high sediment and nutrient concentrations, and that clean rivers in the GBRL are not a great threat to coral reefs.

The SSC data was also used to develop an empirical model, which predicts SSC for a specific site using just wind data. The model is accurate enough to be used in environmental monitoring to predict an expected SSC, which can be prepared with observed SSC from a site where marine construction is taking place so it can be determined whether the work has increased the SSC to a dangerous level. This makes it an important tool as many such construction projects occur in the GBRL each year and there is no other accurate method of determining what the natural SSC would be if work was not taking place.

A new instrument was also developed to infer nutrient concentrations in the water column, to try to overcome problems with existing methods. The instrument works by measuring the speed at which algae grow on a glass plate using a fluorometer. Tests were made to determine how well algal growth would relate to nutrient concentrations, if other factors like temperature, light levels and algal type were not controlled. Results showed that growth was too dependent on these other factors to be a good indicator of nutrient concentrations. The sensor could, however, be used to determine the effect nutrients have on algal growth, which in itself is a potential threat to corals.



# Table of Contents

<b>1 - Introduction</b>	<b>1</b>
Influences of Nutrients and Sediments in the GBRL	1
Sediment and Nutrient Inputs to the GBRL	1
Sediments	1
Nutrients	3
Potential Impacts of Sediments and Nutrients	5
Sediments	6
Nutrients	7
Thesis Outline	9
Lugger Bay Reef	11
Study Techniques	16
Prediction of SSC	17
Development of an Algal Growth Sensor	18
Thesis Layout	18
<b>2 - Suspended Sediment Concentrations and Fluorescence in an Inshore Reef Region of the Great Barrier Reef Lagoon</b>	<b>20</b>
Abstract	21
Introduction	22
Study Site	26
Methods	29
Data Collection	29
Results	31
SSC and Fluorescence Statistics	31
Temporal Distribution of SSC and Fluorescence Levels	33
Spatial Distribution of SSC and Fluorescence Levels	36
Current Data	37
Discussion	38
Spatial Variation in SSC and Fluorescence	38
Relationship between SSC and Fluorescence	39
Flood Plumes and Wave Resuspension	41
Net Sediment Flow	45
Sediment Input from Outside the Region	46
SSC Levels on the Reefs	46
Conclusion	47
<b>3 - A Case Study of Lugger Bay Reef</b>	<b>53</b>
Abstract	54
Introduction	55
Field Site	56
Methods	58
Results	60
SSC and Light Data	60
Phototransects	63
Core Data	64
Discussion	66
SSC and Light	66
Phototransects	68

Coring	69
Conclusion	69
<b>4 - Predicting Suspended Sediment Concentrations on Coral Reefs Using Meteorological Data</b>	<b>73</b>
Abstract	74
Introduction	75
Field Sites	79
Methods	83
SSC Measurements	83
Wind Data	83
Model	84
$K_t(t_{wn})$ – Temporal Wind Weighting Function	85
Wind Direction Weighting Function	87
Tidal effects	88
Model Calibration and Minimisation Function	88
Model Evaluation	89
Results	90
SSC Measurements	90
Model Results	94
Tidal Influence	94
Generated Model Parameters	95
Model Predictions	97
Discussion	105
Conclusion	108
<b>5 - Algal Growth Sensor</b>	<b>111</b>
Abstract	112
Introduction	113
Methods	116
Instrument Design and Construction	116
Instrument Testing	118
Results	119
Discussion	125
Conclusions	128
<b>6 – Conclusions</b>	<b>131</b>
SSC and Fluorescence Throughout the Region	132
Lugger Bay Reef	133
SSC Prediction	134
Algal Growth Sensor	134
Overview	135
<b>7 - Future Work</b>	<b>136</b>
<b>8 - Glossary</b>	<b>137</b>
<b>9 – References</b>	<b>138</b>

# List of Figures

<b>Figure 1.1:</b> Fluxes of nitrogen in the Great Barrier Reef Lagoon.	4
<b>Figure 1.2:</b> Reservoirs of nitrogen in the Great Barrier Reef Lagoon.	5
<b>Figure 1.3:</b> Location of Luggier Bay in the North Queensland area.	12
<b>Figure 1.4:</b> Luggier Bay and the surrounding area.	13
<b>Figure 1.5:</b> Photographs of Luggier Bay Reef.	15
<b>Figure 2.1:</b> Location of Luggier Bay and Family Islands region in North Queensland.	26
<b>Figure 2.2:</b> Instrument locations in Luggier Bay and in the surrounding area.	27
<b>Figure 2.3:</b> Box plots of the SSC data.	32
<b>Figure 2.4:</b> Box plots of the fluorescence data.	33
<b>Figure 2.5:</b> Time series of SSC and Fluorescence from 21/12/03 to 25/01/04.	34
<b>Figure 2.6:</b> Time series SSC and Fluorescence data from 24/03/04 - 28/04/04.	35
<b>Figure 2.7:</b> Longshore current at north of Tully site with a 7 day rolling mean.	38
<b>Figure 2.8:</b> SSC vs. distance from shore for the various sites.	39
<b>Figure 2.9:</b> Correlation between fluorescence and SSC.	40
<b>Figure 2.10:</b> Correlation between SSC and river discharge and between fluorescence and river discharge for Bedarra Island and Luggier Bay Shore.	42
<b>Figure 2.11:</b> Correlation between SSC and Tully River discharge (top), and between SSC and wave height (bottom).	43
<b>Figure 2.12:</b> Correlation between fluorescence and SSC during Tully River high and low discharge events for SSC events of over 200 mg/l for Luggier Bay Shore.	45
<b>Figure 3.1:</b> Location of Luggier Bay Reef in the North Queensland region.	57
<b>Figure 3.2:</b> Photographs of Luggier Bay Reef.	58
<b>Figure 3.3:</b> Diagram of Luggier Bay Reef with the three instrument sites, four percussion core sites and two phototransects shown.	59
<b>Figure 3.4:</b> Box plots of SSC data from the three Luggier Bay instrument sites.	61
<b>Figure 3.5:</b> Light and SSC time series for Luggier Bay.	62
<b>Figure 3.6:</b> Example sections of the phototransects.	64
<b>Figure 3.7:</b> Phototransect analysis.	65
<b>Figure 3.8:</b> Reef cross section with the locations and depths of the percussion cores included.	66
<b>Figure 3.9:</b> Correlation between SSC and light.	68
<b>Figure 4.1:</b> Map of data collection locations: Port Douglas, Luggier Bay/Family Islands and Nelly Bay.	80
<b>Figure 4.2:</b> SSC measurement sites: Port Douglas, Luggier Bay/Family Islands, and Nelly Bay Harbour.	81
<b>Figure 4.3:</b> Time taken for the generation of a fully developed sea.	86
<b>Figure 4.4:</b> Example of an expected $k_t(t_{wn})$ temporal wind weighting function verses time.	87
<b>Figure 4.5:</b> Wind direction weighting function $k_\theta$ .	88
<b>Figure 4.6:</b> Box plots of the hourly SSC data.	91
<b>Figure 4.7:</b> Box plots of the daily averaged SSC data.	93

<b>Figure 4.8:</b> Temporal wind weighting, $k(t_{wn})$ , for the various sites.	95
<b>Figure 4.9:</b> Directional wind weighting, $k_{\theta}$ , for the various sites.	96
<b>Figure 4.10:</b> Modelled/predicted and observed hourly SSC for Port Douglas Site z, 2004.	98
<b>Figure 4.11:</b> Daily average of modelled/predicted and observed SSC for Port Douglas Site z, in 2004.	99
<b>Figure 4.12:</b> Daily average of modelled/predicted and observed SSC for Port Douglas Site y, 2004.	100
<b>Figure 4.13:</b> Daily average of modelled/predicted and observed SSC for Nelly Bay in 2001.	101
<b>Figure 4.14:</b> Daily average of modelled/predicted and observed SSC for Luggar Bay, and the Tully River discharge in 2003 to 2004.	102
<b>Figure 4.15:</b> Daily average of modelled/predicted and observed SSC for Thorpe Island and the Tully River discharge in 2003 to 2004.	103
<b>Figure 4.16:</b> Daily average of predicted and observed SSC for Bedarra Island and the Tully River discharge in 2003 to 2004.	104
<b>Figure 5.1:</b> Principle of operation of sensor.	117
<b>Figure 5.2:</b> Photographs of the Algal Growth Sensor.	118
<b>Figure 5.3:</b> Fluorescence time series data.	120
<b>Figure 5.4:</b> Comparison between algal growth rate, nitrate concentration, temperature and number of hours of bright sunlight.	122
<b>Figure 5.5:</b> Correlations between algal growth rate and: nitrates, temperature, and number of hours of bright sunlight.	123
<b>Figure 5.6:</b> Algal growth and turbidity for Middle Reef.	125

## List of Tables

<b>Table 2.1:</b> Deployment times at the various locations.	31
<b>Table 2.2:</b> Mean SSC and Fluorescence levels and the ratio of fluorescence to SSC at the different sites in the area.	36
<b>Table 2.3:</b> Fluorescence/SSC for the different terciles of SSC.	37
<b>Table 4.1:</b> Statistical information for the hourly SSC data from the different sites.	92
<b>Table 4.2:</b> Statistical information for the daily averaged SSC data from the different sites.	94
<b>Table 4.3:</b> Parameter values for the various sites.	97
<b>Table 4.4:</b> Evaluation results of model predictions for the various locations for both the training and prediction periods.	105