Predicting the habitat distribution and grazing of coral reef fish

Submitted by **Sonia Bejarano Chavarro**,
to the University of Exeter as a thesis for the degree of
Doctor of Philosophy in **Biological Sciences**,
December **2009**.

I certify that all material in this thesis which is not my own work has been identified and that no material has previously been submitted and approved for the award of a degree by this or any other University.

(signature) .....

To Devon, a small farewell
For my peace (*your gift*)
Deep gratitude from the middle of my heart.

ABSTRACT

Although today coral reefs need to be managed to ensure their persistence in the challenging conditions imposed by a rapidly changing environment, practitioners worldwide often lack adequate tools to achieve this. Spatial patterns of the abundance of reef resources, but also of the processes that govern reef recovery after disturbance, need to be mapped at relevant scales to identify priority conservation measures. In this thesis I took important steps towards the construction of adequate tools for reef managers: towards creating maps of reef resilience. The first step comprised the accuracy enhancement of thematic maps to discriminate typical forereef habitats that differ in their structural complexity. The second step consisted of the creation of statistical models to predict spatial patterns of the density and biomass of several fish species including grazers. To date, fish species richness can be mapped but not the spatial patterns of abundance or biomass of key species of reef fish. Here, I demonstrate that it is possible to predict spatial patterns of the abundance of key species of grazers across large scales on Caribbean reefs by mapping their acoustic roughness. The third and fourth steps focused on improving our understanding of the process of parrotfish grazing on Pacific reefs. I created models to predict the grazing impact of populations of grazers from their abundance data incorporating sources of spatio-temporal variability in their grazing behaviour. Although grazing of Pacific parrotfish communities is a subject of growing concern and several aspects of its dynamics are well understood on the Great Barrier Reef, this thesis contributes with two major future goals: (1) to rank Micronesian parrotfish species according to their relative contribution to grazing impact and (2) to aid the generation of maps of grazing.

TABLE OF CONTENTS

ACKNOWLEDGEMENTS……..…….....**8**
LIST OF TABLES...……...**10**
LIST OF FIGURES...……**12**
LIST OF ABBREVIATIONS…….... **15**
DECLARATION FROM THE AUTHOR...……...….**17**

CHAPTER 1: GENERAL INTRODUCTION……**18**

1.1. Coral reef ecosystems today……..19
1.2. What is resilience and what are its sources?.....21
1.3. Grazing as an important source of resilience……22
1.4. Effective ecosystem management of today's coral reefs……..23
1.5. The importance of scale for management…….....24
1.6. The role of remote sensing.……25
1.7. Synopsis of this thesis……....27
1.7.1. Combining optical and acoustic data to enhance the accuracy of coral reef habitat maps……....27
1.7.2. Predicting the structural complexity of reefs and fish abundance using RoxAnn……...28
1.7.3. Predicting parrotfish grazing impact in Palau, Micronesia...……..30
1.8. Creating continuous maps of fish grazing: a future goal……...31
References……**32**

CHAPTER 2. Combining optical and acoustic data to enhance the accuracy of coral reef habitat maps……**47**

Abstract…….....**48**
1. Introduction……....**49**
2. Methods…….....**53**
2.1. Study area……..53
2.2. Acquisition of optical data……53
2.3. Acquisition of acoustic data……..54
2.4. Ground-truthing……55
2.5. Data processing……..56
2.5.1. Optical data……...56
2.5.2. Acoustic data…….....57
2.6. Unsupervised classification of different treatments……...58
2.7. Accuracy assessment……..58
3. Results.....**61**
3.1. Benefit of optical-acoustic data combination.……...61
3.2. Relative contribution of acoustic parameters…….....62
3.3. The value of in -band depth correction……..65
4. Discussion…….....**67**
4.1. Comparison with other studies……...71
5. Conclusions…….....**75**
Acknowledgements...…….....**76**

References….....**76**

CHAPTER 3: Predicting structural complexity of reefs and fish abundance using RoxAnn…...……**85**

Abstract……..…….....**86**
1. Introduction……**87**
2. Methods…….....**91**
2.1. Study area……...91
2.2. Field surveys……..92
2.2.1. Fish census and topographic complexity……..92
2.2.2. Acquisition of acoustic data……93
2.3. Data analysis……..95
2.3.1. Fish abundance and biomass…….....95
2.3.2. Acoustic roughness (E1)……...95
2.3.3. Scope of RoxAnn's E1 to predict topographic complexity……..95
2.3.4. Species relationships with topographic complexity and E1……96
2.3.4.1. Common species……..96
2.3.4.2. Uncommon species……..97
2.3.5. Scope of RoxAnn's E1 to predict patterns of fish abundance……..97
3. Results……..**99**
3.1. Scope of E1 to predict topographic complexity…….....99
3.2. Species relationships with topographic complexity and E1…… 100
3.2.1. Predicting the abundance of common species……100
3.2.2. Predicting the abundance of uncommon species……109
3.3. Scope of E1 to predict patterns of fish abundance……...111
4. Discussion……...……**113**
4.1. The scope of RoxAnn's E1 to predict patterns of fish abundance……...118
5. Conclusions……....**119**
Acknowledgements……...……**120**
References…….....**120**

CHAPTER 4. Predicting parrotfish grazing impact in Palau, Micronesia……**129**

Abstract.....**131**
1. Introduction……...**132**
2. Methods……..**136**
2.1. Study area……136
2.2. Data collection……139
2.2.1. Parrotfish biomass……...139
2.2.2. Parrotfish bite rate and grazing selectivity……...139
2.2.3. Parrotfish bite areas and volumes……...140
2.3. Data analysis……142
2.3.1. Effect of biophysical variables on parrotfish bite rate……142
2.3.2. Grazing selectivity……..143
2.3.3. Parrotfish bite area……..143
2.3.4. Grazing impact of four parrotfish species……...144
3. Results……**146**
3.1. Parrotfish biomass……146

3.2. Effect of biophysical variables on parrotfish bite rate……148
3.2.1. *Chlorurus sordidus*: effect of site, life phase, body size, and time of day……148
3.2.2. Lukes reef: differences between a common scraper and excavator of similar size……149
3.2.3. New-drop off: differences among excavators……149
3.3. Grazing selectivity……149
3.4. Parrotfish bite area and volume……149
3.5. Grazing impact……151
3.6. Is relative biomass a good proxy for relative grazing impact?……152
4. Discussion……**153**
4.1. Parrotfish biomass……153
4.2. Effect of biophysical variables on parrotfish bite rate……155
4.3. Area grazed per bite……158
4.4. Is relative biomass a good proxy of relative grazing impact?……160
Acknowledgements……**163**
References……**163**

CHAPTER 5. The effect of tides on the behaviour of parrotfishes: Budgeting time between grazing and spawning……**173**

Abstract……**174**
1. Introduction……**175**
2. Methods……**177**
2.1. Study area……177
2.2. Data collection……178
2.3. Data analysis……180
2.3.1. Spawning behaviour and synchrony with the tidal cycle and times of day……180
2.3.2. Effect of time of day and tidal height on the spawning frequency……180
2.3.3. Quantitative effects of spawning on grazing rates……180
2.3.4. Periodicity and frequency of intra and inter-specific interactions……181
3. Results……**182**
3.1. Spawning behaviour and synchrony with the tidal cycle……182
3.2. Effect of time of day on reproductive behaviour……184
3.3. Quantitative effects of spawning on grazing rates……184
3.4. Periodicity and frequency of intra and inter-specific interactions……186
4. Discussion……**187**
4.1. Spawning behaviour and daily synchrony with the tidal cycle……188
4.2. Quantitative effects of spawning on grazing rates……191
4.3. Periodicity and frequency of intra and inter-specific interactions……192
Acknowledgements……**194**
References……**195**

CHAPTER 6. GENERAL DISCUSSION……200

6.1. Combining optical and acoustic data to enhance the accuracy of coral reef habitat maps……202
6.2. Predicting the structural complexity of reefs and fish abundance using RoxAnn……204

6.3. Predicting parrotfish grazing impact in Palau, Micronesia……..206
6.4. The effect of tides on the behaviour of parrotfishes: Budgeting time between spawning and feeding……...209
References……...212