TROPHIC DYNAMICS IN AUSTRALIAN SEAGRASS BEDS: UNRAVELLING LINKAGES FROM NUTRIENTS TO FISH

Paul H. York

Thesis submitted in fulfilment of the requirements for the Degree of Doctor of Philosophy at the University of Technology, Sydney

June 2010

UNIVERSITY OF TECHNOLOGY SYDNEY

CERTIFICATE OF AUTHORSHIP/ORIGINALITY

I certify that the work in this thesis has not previously been submitted for a degree nor has it been submitted as part of requirements for a degree except as fully acknowledged within the text.

I also certify that the thesis has been written by me. Any help that I have received in my research work and the preparation of the thesis itself has been acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

Paul H. York

ACKNOWLEDGEMENTS

Firstly I'd like to acknowledge my supervisors, Dave Booth and Brendan Kelaher for their advice, guidance and encouragement during my candidature. Brendan played a large part in the early development of the research that went into this thesis and continued to be of great assistance after leaving UTS. Dave has always been there when I needed him, particularly towards the finish with encouragement and advice during my thesis writing. Thank you both. Not only have you been excellent mentors but also the very best of friends and I'm sure that will continue into the future.

I would also like to thank Melanie Bishop and Paul Gribben, for their very insightful comments on some of my data chapters and Sue Plunkett- Cole for her thorough editing of my writing and grammar. I need to acknowledge Maria Schreider for advice on sampling epifauna, Marcus Gregson, Bruce Pease and NSW Fisheries for the use of their BRUVs and gill nets and Roger Springthorpe for assistance in invertebrate identification.

I would like to thank the long list of friends and colleagues that helped me out with field work. I hope I haven't left anyone out: Chris Rawson, Carla Harris, Melanie Lewis, Matt Cole, Jason Hainke, Emily Buckle, Marcus Gregson, Alexandra Griffin, Skye Taylor, David Booth, Ralph Alquezar, Chris Gillies, Brendan Kelaher, Melinda Coleman, Cliff Seery, Damian Licari, Peter Biro, Christa Beckmann, Will Figueira, Jason Brennan, Stephen Summerhayes, Melanie Bishop, James van den Broek, Sean Newham, Chris Richard, Jennifer Clark, Geoff Gardiner, Cecilia Ericson, Tara Vaughan, and Cybele Shorter. Gabriel Shaw, Jennifer Clark, Chris Richard, Jo Moore and Geoff Gardiner also provided many hours of their time to the sorting of samples in the lab and construction of experimental cages.

On a more personal note I am especially grateful to my parents, Carmel and Ian for their patience and support and the many hours of assistance they provided with data entry and the construction of artificial seagrass units. To Sue, my partner of the last few years, thanks for all your emotional and financial support and putting up with the myriad of moods that a PhD candidature can bring on. Lastly I would like to thank my post-grad colleagues at UTS for their friendship and support and my flatmates over the last four years at Coogee.

TABLE OF CONTENTS

General Abstract xi

Chapter 1 Introduction **1**

Food Webs, Trophic Cascades & Bottom-up Forcing 1

Predator-Prey Models for Predicting Trophic Dynamics 2

Nutrient Enrichment, Eutrophication and Secondary Production 3

The Importance of Seagrasses and Seagrass Food Chains 4

Seagrass Decline 5

Study System 6

Significance and Aims of this Study 8

Thesis Outline 10

Chapter 2 General Methods **12**

Location of Study 12

Nutrient Samples 14

Description of General Sampling Methods 15

Descriptions of Macrofauna and Taxonomic Resolution 19

Statistical Analysis 21

Chapter 3 Changes in seagrass faunal assemblages under different nutrient regimes and levels of anthropogenic disturbance **22**

Abstract 22

Introduction 23

Methods 25

Results 28

Discussion 47

Chapter 4 Trophic dynamics in temperate seagrass food chains **51**

Abstract 51

Introduction 52

Methods 54

Results 57

Discussion 59

Chapter 5 Growth and survival of juvenile fish in seagrass under different nutrient regimes **62**

Abstract 62

Introduction 63

Methods 65

Results 69

Discussion 80

Chapter 6 Top-down and bottom-up forcing in temperate Australian seagrass beds **85**

Abstract 85

Introduction 86

Methods 88

Results 90

Discussion 97

Chapter 7 General Discussion **100**

Changes in Biomass and Community Structure with Nutrient Enrichment 101

Modelling and Monitoring Seagrass Ecosystems 105

Management Implications 108

Future Research 110

Conclusion 111

References **113**

Appendices **135**

Appendix I: Methods for pilot study on sampling piscivorous fish in shallow seagrass beds 135

Appendix II: Measures of abundance and species richness of piscivores and other guilds of fish for the five different sampling methods 139

Appendix III: Summary of the costs, benefits and limitations of the five sampling methods employed during the study. 140

Appendix IV: Experimental design for 3 factor ANOVA 141

LIST OF FIGURES

Figure 2.1: Map of Brisbane Water, Pittwater, the lower Hawkesbury River estuary and Broken Bay 13

Figure 2.2: BROMAR sampler, specifically designed to collect seagrass, epiphytes and mesograzers........ 18

Figure 3.1: MDS plots of fish assemblages 36

Figure 3.2: Total abundance and species richness of juvenile fish at all sites over three sampling periods.. 37

Figure 3.3: Abundance of carnivorous juvenile fish, omnivorous juvenile fish and *Ambassis jacksoniensis*. 38

Figure 3.4: Abundance of *Arenigobius frenatus Redigobius macrostoma* and *Pandaculus lidwilli*. 39

Figure 3.5: MDS plots of grazer assemblages 44

Figure 3.6: Total abundance and species richness of mesograzer assemblages 45

Figure 3.7: Abundance of amphipods and gastropods 46

Figure 4.1: Biomass of algae, grazers, juvenile fish, and piscivorous fish in low ambient nutrient levels and nutrient enriched sites. 58

Figure 5.1: Field enclosures at Mullet Creek. 65

Figure 5.2: Nutrient levels for enriched and ambient enclosures at the middle and end of the manipulative experiment 71

Figure 5.3: Water temperature inside and outside of enclosures. 72

Figure 5.4: Biomass of seagrass biomass, algal load and mesograzer biomass for enriched and ambient nutrient treated enclosures and adjacent seagrass beds. 73

Figure 5.5: Fish survivorship; and biomass for enriched and ambient mesocosms. 74

Figure 5.6: Fish lipid content & proportional weight loss for enriched and ambient mesocosms. 75

Figure 5.7: Ammonia and nitrate/nitrite levels for nutrient enriched sites and ambient nutrient sites. 78

Figure 5.8: Seagrass biomass; algal load and; mesograzer biomass for nutrient enriched sites and ambient nutrient sites 79

Figure 5.9: Fish condition measured as lipid content for nutrient enriched sites and ambient nutrient sites. 80
Figure 6.1: Seagrass canopy growth and seagrass biomass for all treatments at the conclusion of the experiment. 93
Figure 6.2: Algal load on seagrass leaves and grazer biomass at the conclusion of the experiment........ 94
Figure 6.3: MDS plot of epiphyte grazer assemblages. 95
Figure 6.4: Abundance and species richness of grazer assemblages at the conclusion of the experiment 96

LIST OF TABLES

Table 2.1: Measures of abundance and species richness of piscivorous fish for four different sampling methods used during a pilot study. 17

Table 2.2: List of fish species caught during field sampling in this study....................... 20

Table 3.1: ANOVA results for catchment attributes upstream of sampling sites. 29

Table 3.2: ANOVA results for habitat characteristics of sites.. 29

Table 3.3: ANOVA results for water quality parameters. 29

Table 3.4: Water quality, habitat and catchment attributes of each site. 30

Table 3.5: Seagrass attributesfor each site at each sampling periods. 30

Table 3.6: PERMANOVA results for differences in fish assemblages 33

Table 3.7: SIMPER analysis of differences between fish assemblages in ambient and nutrient enriched sites for each sampling period.. 34

Table 3.8: ANOVA results for fish abundance, species richness and major taxonomic groups.. 35

Table 3.9: PERMANOVA results for differences in grazer assemblages. 41

Table 3.10: SIMPER analysis of differences between grazer assemblages 42

Table 3.11: ANOVA results for grazer abundance and species richness and abundance of major taxonomic groups. 42

Table 3.12: Correlation coefficients of BIO-ENV analysis to test for relationships between fish and grazer assemblage and environmental and habitat variables. 43

Table 4.1: Predicted responses to trophic levels when exposed to sustained bottom-up forcing in trophic cascades with four levels.. 53

Table 5.1: Repeated-measures MANOVA results for differences in nutrient levels....... 70

Table 5.2: ANOVA for seagrass, algae, grazer and fish biomass.................................. 70

Table 5.3: ANCOVA for lipid content and fish growth.. 70

Table 5.4: ANOVA for nutrient levels and seagrass, algae and grazer biomass. 77

Table 5.5: ANCOVAnalysis of covariance for lipid.. 77

Table 6.1: ANOVA table for differences in seagrass algae and grazer attributes. 92

GENERAL ABSTRACT

The study of food webs and trophic dynamics has been a major endeavour for biologists for over half a century. The major aim of trophic ecology has been to explain the complex structures and interaction of food webs using simple models and generalities. A key debate in this research field has been the extent to which trophic structures of communities are driven by resource or consumer control. This issue has important implications for the management of marine ecosystems with anthropogenic disturbance rapidly altering bottom-up (e.g. nutrient enrichment) and top-down (e.g. fisheries exploitation) processes. To enhance understanding of bottom up and top-down influences in productive estuaries, this study investigated a prominent four level food chain (epiphytic algae, mesograzers, juvenile fish, and piscivorous fish) in seagrass habitats. Large-scale mensurative field experiments were combined with manipulative experiments to gain an improved understanding of changes in biomass and community structure of trophic levels under different nutrient loading and to determine the type of functional response driving these changes.

In general, epiphyte and grazer biomass were greater in developed catchments with higher nutrient loads during long-term field sampling of systems approaching equilibrium. However, a decoupling from the epiphyte trophic pathway was evident in higher trophic levels. The biomass of carnivorous juvenile fish and large piscivores displayed no significant change across the nutrient gradient of this study. This pattern indicates that a ratio-dependent functional response would be most appropriate for modelling the lower trophic levels and their responses to nutrient enrichment. However, more complex models taking into account other factors such as trophic transfer and subsidy are required for models across all four trophic levels.

Short-term experiments involving epiphytes, grazers and juvenile fish that manipulated nutrient levels and predation rates often behaved in ways that contradicted the patterns described above for long-term studies. In particular, manipulative studies showed strong evidence for top-down control sometimes resulting in lower or similar levels of epiphytes in enriched plots compared to ambient controls.

The structure of fish assemblages was influenced by the nutrient status of the waters they inhabited. Assemblages from developed and undeveloped catchments separated into distinct communities with higher abundances of fish in low nutrient waters. The species that contributed most to these differing assemblages were small pelagic carnivores (*Ambassis jacksoniensis* and *Redigobius macrostoma*). These species appeared to be sensitive to poor water quality making them candidates for bio-indicators of anthropogenic disturbance in catchments.

Enclosure experiments and mensurative field sampling found that growth, survival and condition of juvenile trumpeter (*Pelates sexlineatus*) were greater under ambient nutrient levels despite increased prey items in nutrient enriched sites. This suggests that the positive indirect effects of increased trophic support from nutrient enrichment may have been countered by direct negative effects of toxicity either from the nutrients in their dissolved forms of ammonia; nitrate; or from other anthropogenic pollutants such as metals or hydrocarbons.

Overall, nutrient enrichment of coastal waters in south-eastern Australia promoted epiphyte growth that may compete with seagrasses for light, causing stress and possible declines in seagrass health and distribution. My study, however found greater seagrass biomass at some sites with nutrient enrichment suggesting moderate increases to nitrogen-limited systems may be beneficial to seagrasses. It also appears that the increase in primary productivity associated with nutrient loading did not translate into an increase in biomass of juvenile fish or piscivores in seagrass habitats, providing no benefit to fisheries production. Given the potential for nutrient enrichment to alter trophic structure in coastal waters and to have negative impacts on seagrass health it is recommended that an integrated system of management be implemented. This should include further targeted research for a better understanding of seagrass trophic systems, monitoring of environmental indicators that alert catchment managers to early signs of eutrophication, remediation of existing eutrophic systems through nutrient reduction mechanisms and planning policies that identify and afford greater protection to ecologically-important habitats such as seagrass; and estuaries with high residence times that are more vulnerable to eutrophication.