Ecology of Crustose Coralline Algae; Interactions with Scleractinian Corals and Responses to Environmental Conditions

Thesis submitted by

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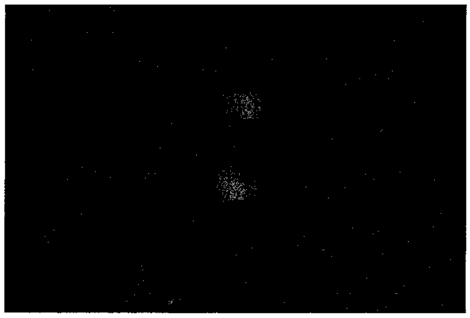
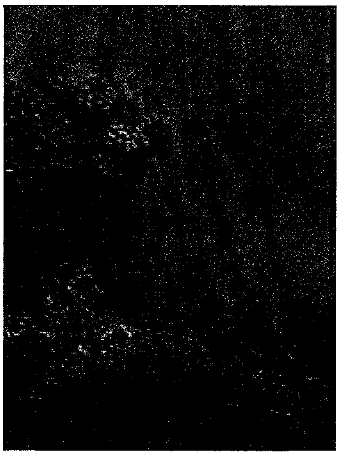


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Statement of Contributions by Others

I gratefully acknowledge the support of an International Postgraduate Research Scholarship (IPRS) Award from the James Cook University (JCU). I would like to extend my gratitude to the Cooperative Research Centre for the Great Barrier Reef World Heritage Area (CRC Reef), and the Australian Institute of Marine Science (AIMS) for funding this research.

Some of the work I carried out for my PhD was collaborative, jointly published and/or done with technical, theoretical, statistical, editorial or physical assistance of others. I fully acknowledge the contributions by others as outlined below and detailed in the acknowledgements. To the best of my knowledge, all other work was done and written independently.

Chapter 2

Dr. Glenn De'ath provided statistical assistance. Dr. Katharina Fabricius and Dr. Robert Steneck contributed to the intellectual and editorial work.

Chapter 3

This chapter contains research that is part of a jointly published paper. Geoff Eaglesham conducted water analysis and characterization. Sediment analysis and characterization was carried out by Miriam Weber (Diplom thesis, 2003). Both Dr. Katharina Fabricius and Dr. Andrew Negri contributed to the intellectual, written and editorial work (see Appendix one, publication No. 2).

Chapter 4

This chapter contains research that is part of a collaborative effort (see Appendix one, publication No. 3). Tiles were deployed by myself (inshore reefs GBR), Emre Turak (offshore reefs GBR) and Robert Steneck (reefs in the Caribbean). Both Dr. Robert Steneck and Emre Turak contributed to the intellectual work. Dr. Glenn De'ath provided statistical advice and Dr. Katharina Fabricius assisted with editorial work.

Chapter 5

This chapter contains research that is part of a jointly published paper. Dr. Glenn De'ath provided statistical assistance. Dr. Andrew Negri performed CCA chemical extractions, and provided theoretical and editorial assistance to the manuscript. Dr. Katharina Fabricius contributed to the intellectual and editorial work (see Appendix one, publication No. 1).

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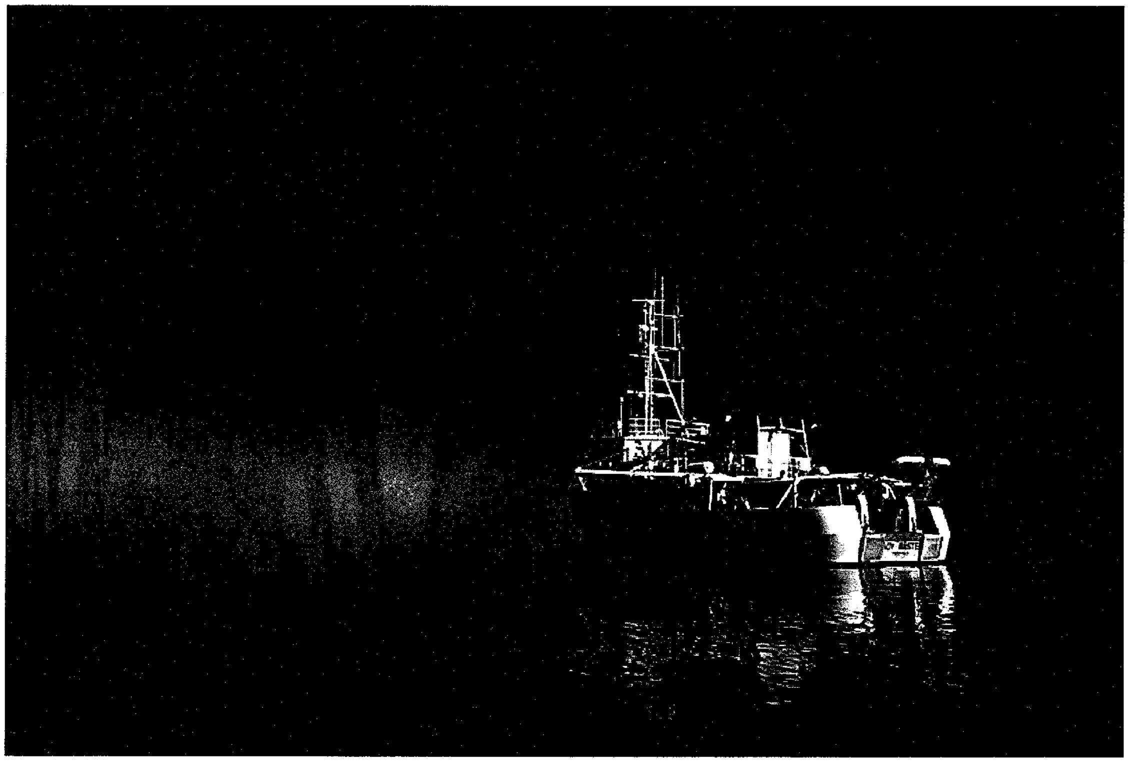

Dedication

For all the women who made me strong, for all the mermaids who coaxed me under the sea and for the man who first took me diving, Daddy

Abstract

Crustose coralline algae (CCA) are considered a key functional group in coral reef ecosystems. Changes in the abundances of certain CCA species can directly regulate the abundance of other components of reefs, in particular corals, and can therefore result in changes in structure and function of this marine ecosystem. This thesis assesses important questions on what controls distribution and abundance patterns of tropical CCA species along environmental gradients, their responses to sedimentation and the herbicide diuron, and species-specific differences in their roles in inducing or inhibiting coral recruitment, hence contributing to the structuring of coral reefs.

The taxonomic composition of CCA is described for the inshore and offshore reefs within the central and northern Great Barrier Reef (GBR). Twenty-three species from twelve genera and three subfamilies of Corallinaceae were identified to species level using reproductive and vegetative morphology and anatomical features as diagnostic characters. Distribution and relative abundance of the species were compared along gradients in depth and across the shelf, and along a set of environmental variables such as slope angle and sedimentation. Changes across the continental shelf were observed in CCA cover and CCA community composition, as well as in the environmental variables slope angle, sediment deposits, and water clarity. Percent cover of CCA increased more than four-fold across the shelf. Inshore reefs were dominated by thin leafy non-adherent corallines (i.e. *Mastophora pacifica*), whereas offshore reefs were dominated by thick adherent species (i.e. *Porolithon onkodes* and *Neogoniolithon fosliei*). Abundances of several species were significantly related to cross-shelf distance, depth and sedimentation. For example, the most abundant CCA, *Porolithon onkodes* was 4 times more abundant on offshore reefs compared to inshore reefs, and preferred shallow depths (2 to 5 m) and low sediment deposits. Conversely, the most abundant species on the inshore reefs, *Hydrolithon reinboldii,* decreased in abundance across the shelf, preferred deeper depths (8 to 12 m) and was not affected by high levels of sediment. Differences in CCA communities between inshore and offshore reefs may however be additionally related to the factors of wave force, grazing and water clarity. On the inshore reefs, the reduced cover of CCA, the dominance of thin and leafy species and the reduced abundance of thick consolidators have profound implications for differences in the ecosystem structure.

At present, the degree to which human activity can affect abundance and species composition of CCA on reefs is poorly understood. The herbicide diuron (N'-(3,4- dichlorophenyl)-N, N-dimethylurea) is detectible in many inshore sediment samples along the central Queensland coast. Organisms living on some of the inshore coral reefs of the GBR are regularly exposed to river plumes transporting this herbicide. This study compares physiological responses and survival of CCA that were exposed to diuron and to sedimentation, separately and in combination, in controlled time course laboratory experiments, using pulse-amplitude modulation chlorophyll fluorometry. The results demonstrate that sediment deposition and exposure to diuron when applied in isolation can negatively affect the photosynthetic activity of CCA, but were often reversible depending on diuron concentration and sediment type. Significant reductions in effective quantum yields ($\Delta F/F_{m'}$) of photosystem II in CCA species were observed at nominal diuron concentrations greater than 1 μg L^{-1}. Exposure to fine (<63 μm grain size) nutrient-rich estuarine sediments reduced $\Delta F/F_{m'}$ more than exposure to the same amount of fine (<63 μm grain size) calcareous sediments. There are clear differences in sedimentation tolerance between species, with an inshore species (*H. reinboldii*) being more sediment tolerant than two offshore species (*P. onkodes* and *N. fosliei*). Sedimentation stress is however significantly enhanced by trace concentrations of diuron, and recovery from a combined sediment and diuron exposure was still incomplete after 9 days. The finding of synergistic effects of simultaneous exposure to sedimentation and diuron on CCA has implications for the recruitment of the vast number of reef organisms specialized to settle on CCA.

The ability of coral larvae to identify an appropriate site for settlement and metamorphosis is critical for recruitment. Crustose coralline algae are known to induce metamorphosis of coral larvae in the laboratory. The aim of this field study was to determine what types of substrata (namely reef-dwelling species of CCA) coral recruits settle on and at what orientation (i.e. upper, lower or vertical surfaces). This study was conducted in 3 regions: in the GBR on inshore and offshore reefs, and in the Caribbean. After one year, the amount of unoccupied substrata (bare), and the space occupancy of CCA, *Peyssonnelia sp*., invertebrates and turf algae on the settlement tiles varied between the 3 regions. On offshore reefs in the GBR the percent of CCA on the tiles was greatest (26%) and turf algae lowest (5%). On average, 89% of coral recruits were found on the bottoms and sides of the settlement tiles. Most coral recruits in the GBR and in the Caribbean attached to a widespread but rare CCA, *Titanoderma prototypum*, that overall comprised less the 5% of the coralline flora on natural reef surfaces, but as a pioneer species, nevertheless covered 2.5% of the settlement tiles. Most other reef-dwelling organisms, such as other encrusting algae (i.e. the CCA species *H. reinboldii* and *Porolithon sp.* and the non-coralline crust *Peyssonnelia sp*., which induce metamorphosis under laboratory conditions), and some invertebrates (specifically polychaetes, foraminifera and attached bivalves), supported significantly lower coral recruit densities. In all regions combined, only 0.1% of the coral recruits settled onto turf algae despite it covering 14% of the tiles, and 0% settled on sediment-covered surfaces, macroalgae and certain species of dominant CCA. *Titanoderma prototypum* may provide a good attachment surface in microhabitats where competition and grazing from other reef organisms is low. This research identifies the available settlement substrata for coral settlement in the GBR and Caribbean and highlights the critical role a single species can play in the structure and function of a highly complex ecosystem.

Several species of CCA are known to induce coral settlement, however CCA also employ physical and biological anti-settlement defence strategies at varying effectiveness. This study describes the chemical and physical recognition and ranking of five CCA species and inert settlement substrata by coral larvae, and the subsequent survival of these larvae on the varying substrata. Settlement on the most preferred substratum, *T. prototypum*, was 15 times higher than on the least preferred substratum, *N. fosliei*. The rates of post-settlement survival of the corals also varied among CCA species in response to their anti-settlement strategies (shedding of surface cell layers, overgrowth and potential chemical deterrents). Rates of larval settlement, post-settlement survival and the sensitivity of larvae to chemical extracts of CCA were all positively correlated across the five species of CCA. Non-living settlement substrata on coral reefs are sparse, consequently the presence of only a few

CCA species that facilitate coral recruitment has important implications for structuring the reef ecosystem.

These four studies have extended our knowledge of basic ecology of CCA and their important role in structuring coral reefs. They have also advanced our knowledge of how the mosaic of benthic organisms, influenced by human disturbances, affect coral settlement. A small and inconspicuous species of CCA that strongly facilitates and catalyzes coral recruitment on reefs has been identified. The information gained from these studies assists in the understanding of reef recovery, and therefore may contribute to the management and conservation of reef ecosystems.

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