Effects of sedimentation on the structure of a phaeophycean dominated macroalgal community

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Declaration

This thesis contains no material which has been accepted for the award of any other degree or diploma in any university or tertiary institution and to the best of my knowledge and belief contains no material previously published or written by another person except where due reference is made in the text.

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Abstract

Macroalgae are abundant on shallow temperate reef environments, often forming complex communities that comprise several strata. In southern Australia, these assemblages are dominated by large canopy forming taxa from the Orders Laminariales and Fucales. The presence of subtidal fucoid macroalgae differentiates these communities from that elsewhere, and emphasises the need for local studies rather than relying on generalisations made elsewhere.

Like most natural systems, temperate reefs are often threatened by human activity with degradation reported from many locations in close proximity to urban settlements. The work presented in this thesis involves an examination of the temporal and spatial variability in the structure of macroalgal communities from reefs along the Adelaide (South Australia) metropolitan coast. The work looked specifically at the effects of a dispersed sediment plume, resulting from the 1997 beach sand-replenishment dredging program, on shallow sub-tidal reef systems.

An examination of the structure of canopy forming phaeophycean macroalgae in Gulf St Vincent (South Australia), noted large amounts of both spatial and temporal heterogeneity. Notwithstanding, this variation was not random, but demonstrated considerable structure that could be linked to a number of important underlying processes. In particular, macroalgal assemblages appeared as a mosaic of patches, each of which comprised a high-density state clearly dominated by a single genus (*Cystophora*, *Sargassum*, or *Ecklonia*), or alternatively a lower density mixed assemblage (Variable Low Abundance, VLA).

Macroalgal community structure appeared to be driven by biotic interactions at small scales (metres), such that patches comprised of different species of algae in high density states rarely abutted one another. Instead, VLA assemblages frequently formed a buffer being situated between these mono generic patches. In terms of successional processes, the high-density states appeared to be relatively stable whereas the VLA state, at least in some systems, was transitory. This finding was supported by the absence of intermediary high-density states (e.g. a mix of *Cystophora* and *Ecklonia*) implying that state changes must occur via the VLA state following some form of disturbance.

Larger scale patterns appeared to be driven by environmental variation, with factors such as wave exposure influencing habitat suitability for individual species and thereby

affecting community composition. These phenomena were examined in terms of life history strategies that tend to promote stability, and which are common in late successional taxa.

The importance of properties enhancing stability and the role of disturbance was investigated experimentally using a dispersed sediment plume, which entirely engulfed two reefs[1], as a pulse impact. This disturbance was of particular relevance given that degradation of macroalgal communities in close proximity to the City of Adelaide has been, at least in part, attributed to the effects of elevated levels of sediment. Follow up surveys revealed that the sedimentation from the plume had primarily affected newly recruiting individuals, with few juveniles surviving to one year of age. Over the following few years, the effect of this recruitment failure cascaded into the adult stand.

In broader terms, unfavourable climatic conditions prior to the start of the study, including a particularly severe El Niño event, had a widespread effect on local assemblages, causing high levels of both adult and juvenile mortality. As such, at the commencement of the study, macroalgal communities across the study area were in the process of recovery. This was observed at control sites over the duration of the study. In contrast, recruitment failure at the sediment-affected sites retarded the recovery process, exacerbating the problems associated with prior unfavourable climatic events and leaving them in a degraded state.

This study demonstrated that macroalgal assemblages are equipped (under natural conditions) to handle 'normal' environmental fluctuations (such as inter-annual variability). However, the additional stress associated with certain anthropogenic impacts has the potential to push them over the limit, causing degradation. The loss of canopy macroalgae reduces the structural complexity of the system, leading to a concomitant reduction in their ability to recover. As such, these findings are of particular relevance to those charged with the responsibility for managing near-shore marine environments.

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[1] The plume was created accidentally during a dredging operation for beach sand replenishment of Adelaide's eroding shoreline.

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Preface

Macroalgal communities are prominent inhabitants of the near-shore marine environment at temperate latitudes. In southern Australia, assemblages are often dominated by large canopy forming phaeophycean taxa from the orders Laminariales and Fucales. Together they are major primary producers and create important habitat complexity. Yet the ecology and sensitivities of these communities' remain poorly understood.

Recent surveys of macroalgal-dominated reefs have identified a loss of canopy forming species from the northern part of Adelaide's metropolitan coastline. This impact has been attributed to declining water quality in the region; a stance supported by the more voluminous work on local seagrass communities. However, while seagrass decline has primarily been linked to eutrophication and stormwater discharge, macroalgal communities are also likely to have been affected by increased levels of sediment.

Pretext for this work

During November 1997, offshore dredging for beach sand replenishment led to the creation of a large sediment plume that was observed in close proximity to a number of metropolitan reefs, south of Adelaide. The scale of this event presented a unique opportunity to examine the effect of this disturbance on the resident macroalgal communities. In particular, the most likely impact of the sediment plume would be to affect recruiting individuals through a reduction in suitable hard substrate and by smothering propagules. However, in order to address this issue, it was first necessary to develop an understanding of the inherent structure of the system.

This thesis represents an attempt to understand some of the important structural components of brown algal dominated macroalgal communities. The dynamic nature of the system is considered and used as a framework for investigating spatial and temporal changes in structure under natural conditions and in response to environmental perturbation.

Specific aims of the research

The first objective of this study was to examine of local assemblages in order to create a framework that will enable a degree of prediction. Furthermore, it will address the

dynamic processes that give rise to assemblage structure, thereby providing a level of explanation. The use of this procedure will allow for the subsequent testing of a specific disturbance in a robust manner. Specific aims are:

AIM: *To build an understanding of how local canopy dominated macroalgal systems are structured, and whether knowledge of the current state of a patch can be used to determine past or future states.*

AIM: *To quantify the relationship between adult canopy structure and the underlying juvenile assemblage.*

AIM: *To construct a model that effectively describes assemblage structure.*

AIM: *To determine how the reefs in the study area change through time.*

The second objective of this study was to distinguish the effect of the sediment plume as the signal of interest from the influence of other environmental phenomena.

AIM: *To investigate the impact of elevated sediment levels as a pulse disturbance on the recruitment of canopy forming genera of macroalgae.*

AIM: *To identify the longer term effects of the sediment impact.*

Thesis structure and layout

This thesis attempts to embrace some of the complexity displayed by canopy dominated macroalgal systems and explain some of the important components of structure. Using a sediment plume as a case study, the effect of a pulse disturbance is tracked as it propagates through time.

Chapter 1 provides a background and literature review of current knowledge on macroalgal communities. Included here is a description of the uniqueness of South Australia's marine biota and life history treatises for each of the dominant canopy forming genera present in the study area.

Chapter 2 introduces the Gulf St Vincent environment and discusses some of the threats to ecosystem health. Following this, a description of a sediment plume resulting from sand

dredging for beach replenishment is used as the basis for a natural experiment into macroalgal dynamics.

Chapter 3 describes local reef structure based on 4 selected reefs within Gulf St Vincent and explores some of the patterns observed.

Chapter 4 specifically addresses the impact of the sediment plume on algal recruitment dynamics. This is done through a spatial investigation comparing a number of control and impact sites.

Chapter 5 broadens the study, places the state of macroalgal communities in context with other environmental perturbations, and introduces a temporal component. The longer-term effects of the initial disturbance are then placed in the context of the overall state of macroalgal communities.

Chapter 6 summarises the major findings of this research and provides a synthesis of the results in the context of the relevant literature. It also serves to highlight future research initiatives, which would greatly improve knowledge of macroalgal dynamics.