The role of bioturbators in seagrass blue carbon dynamics

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Certificate of Original Authorship

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.

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Date: 27/02/2017

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Preface

This thesis has been prepared in publication format, whereby each chapter represents a manuscript ready for submission to a scientific peer-reviewed journal. Due to this preparation, there will be a degree of repetition across chapter introductions and methodologies. All data chapters are prepared as research articles. As of yet, no individual chapter has been accepted for publication in a peer-reviewed journal.

Two papers (both submitted to journals, not yet in publication) were produced in association with this PhD, but do not form a part of this thesis. These two papers (one review paper, one research article) are attached in the appendix of the thesis. These are both formatted in the style of the particular journal they have been submitted to.

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Abstract

The ability of vegetated coastal habitats to enhance carbon (C) sequestration and sustain C stocks plays an important role in the global cycling of atmospheric CO_2. These blue carbon ecosystems (encompassing seagrass meadows, mangroves, and saltmarshes) are among the most efficient and productive environments for C storage worldwide. In fact, seagrass meadows transfer C into the sediment more efficiently than any terrestrial ecosystem. There is therefore a huge potential to capitalise on these C sinks, and understanding processes that affect the sequestration and storage of C within seagrass ecosystems is essential. There is however a major deficit in our understanding of the factors affecting C cycling in seagrass sediments, and this is how burrowing macrofauna within seagrass sediments affect the flux of C.

Benthic macrofauna ("bioturbators") are a natural component of seagrass environments. Their activity within the sediment potentially has major impacts on seagrass C sequestration, given their influence on organic matter, and relationship with sediment microbes. It is generally accepted that the effects of bioturbators are a poorly studied component of blue C ecosystems. Quantifying the effect of bioturbation on C sequestration is essential in understanding the continuing C sequestration capacity of these systems.

The overarching objectives for this thesis were two-fold; (1) to determine whether bioturbation has a net overall positive or negative effect on seagrass C sequestration; and (2) to evaluate the mechanisms behind these processes in relation to a meadows C flux. To address these objectives, this thesis took a holistic approach, following the burial and decomposition of organic matter (detritus), and investigating the extent of sediment oxygenation and microbial activity. Finally, we were able to quantify the flux of both sediment and detrital-C from the sediment. A number of species were investigated, including globally-distributed Thalassinidean shrimp ("Callianassid"), and the lugworm *Arenicola marina*. The overall findings of this thesis encompass a "scaled-up" approach to the potential impacts of bioturbators on seagrass sediment C stocks.

The results uncovered in this thesis revealed that bioturbation can have varying impacts on both seagrass C stocks, as well as C sequestration. It was shown that not only do bioturbators influence the burial of organic matter (i.e. detritus), bioturbation also

affects the degradation rate of organic matter. The results in this thesis also brought to light that bioturbation stimulated microbial degradation of sediment-bound C stocks, a process known as "microbial priming". The results of this thesis outline that bioturbation ultimately results in favourable sediment conditions for microbial degradation of both detrital and sediment-C. The culmination of these processes may result in "hot-spots" of C loss. However, it is also evident that bioturbation has a larger scale impact on seagrass as a whole ecosystem. We conclude that bioturbation is likely to have ecologically-meaningful impacts on both Australian and global seagrass C sequestration.