THE SEAGRASS RHIZOSPHERE

KASPER ELGETTI BRODERSEN

The Seagrass Rhizosphere

Kasper Elgetti Brodersen

MSc. in Eng. Aquatic Science and Technology
Seagrass Health Research Group
Plant Functional Biology and Climate Change Cluster (C3)

Thesis submitted for the degree of Doctor of Philosophy
at the University of Technology Sydney I June 10, 2016

CERTIFICATE OF ORIGINAL AUTHORSHIP

This thesis is the result of a research candidature conducted jointly with another University as part of a collaborative Doctoral degree. 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 part of the collaborative doctoral degree and/or 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.

Signature of Student:

Date: June 10, 2016

ACKNOWLEDGEMENTS

I would like to thank my supervisors: Michael Kühl, Daniel A. Nielsen, Ole Pedersen and Peter J. Ralph, without whom I would never have been able to complete this PhD thesis and who all provided editorial assistance to this work. Michael you have been the greatest support of all and the best ever imagined mentor during my PhD project. Thank you very much. Daniel you were my solid support at UTS, and patiently helped me sorting my mind especially during the first year of my PhD, which made me stay on track and keep focussed. Thanks. Ole you appeared a bit later in my PhD project, but I will always remember our voyage back to shore at Narrabeen Lagoon (both mentally and physically) with all our sensitive equipment and data in the rubber dinghy; and how you guided me through that challenging phase of my PhD. Peter you have provided the perfect research facility to overcome the challenge of submitting this PhD thesis, and I could not have wished for a better place to undertake my PhD candidature. Thanks.

Friends and colleges: Mads Lichtenberg, Klaus Koren, Jakob Santner, Mathieu Pernice, Nahshon Siboni, Justin Seymour, Paul York, Michael Rasheed, Maria Mosshammer, Kathrine Jul Hammer, Stacey M. Trevathan-Tackett, Laura-Carlota Paz, Sofie L. Jakobsen, Tony Larkum, Anja Frøytrup, Milan Szabo, Katherina Petrou, Dale Radford, Michele Fabris, Joey Crosswell, Jean-Baptiste Raina, Katie Chartrand, Bojana Manojlovic, Peter Davey, Alex Thomson, Jeff Kelleway, Jessica Tout, Daniel Wangpraseurt, Verena Schrameyer, and all the people I have forgotten; thanks for all the fun experiences in the laboratory, good companionships, long scientific and less-scientific talks and nice research. I am looking very much forward to continue our collaborations in the future.

Thanks to my overseas family for supporting me on this personal dream of mine; of both undertaking a PhD, but as much experiencing the adventures and challenges of moving to and living in Australia.

Lastly, in my mind a PhD is like a journey from a to b, where you in the beginning of your PhD stand at the bottom of a mountain, a big impressive mountain with a threatening glacier close to the summit, and you know that somehow in the end of this journey you will have to find yourself on the top of that mountain planting your personal mark, for forever sight, into the solid rocky ground. But as in all other aspects of life, it is important to remember to focus on the journey itself and not on reaching the final goal, as else you will often find yourself forgetting the purpose of your challenge and thus lose yourself on your way ("journey") to the summit. I therefore dedicate my PhD thesis to my little, much beloved, family. Karla, Rufus and Verena, without you guys I could never have done this, and for that I am you forever grateful. Thanks, with all the love of my heart.

Kasper Elgetti Brodersen

June 10, 2016

"Analysing the below-ground biogeochemical microenvironment of seagrasses to determine how changing environmental conditions affect seagrass health"

Table of Contents

List of Figures

List of Tables

Summary

Seagrass meadows are important marine ecosystems providing an array of ecosystem services to aquatic and terrestrial environments including sediment stabilisation, acting as shelter, feeding and nursery grounds for numerous marine species and even mitigating climate change through their ability to capture and store carbon in the sediment for millennia. However, owing to anthropogenic interference, seagrass meadows worldwide are shrinking, putting essential ecosystem functions at risk. Understanding the basic mechanisms that control the fitness of seagrasses is necessary in order to elucidate how human activities and changing environmental conditions is affecting the seagrass ecosystems and what can be done to better manage them. Through a series of experiments employing high-resolution measuring techniques including luminescence imaging, microsensors and novel optical sensor nanoparticles, this thesis explores the mechanisms of seagrass sediment detoxification and nutrient mobilisation, and the effect of environmental stressors on these essential processes.

We show that radial O_2 loss from the below-ground tissue leads to formation of oxic microshields that re-oxidates phytotoxic H_2S in the rhizosphere and thus results in sediment detoxification; a vital seagrass-derived chemical defence mechanism that is adversely affected by water-column hypoxia. These seagrass-driven alterations of the rhizosphere biogeochemistry modulate the microbial community composition at the plant/sediment interface, potentially increasing the rhizospheric nitrogen availability owing to microbial-mediated nitrogen fixation. We also found that the leaf microenvironment largely controls the intra-plant O_2 conditions and thus the below-ground tissue oxidation capacity, where sediment deposition and epiphyte overgrowth on leaves negatively affects the internal plant aeration through multiple pathways, such as (i) enhancing the thickness of the mass transfer impeding diffusive boundary layer around the leaves, (ii) reducing the light availability/quality for photosynthesis, and (iii) enhancing the over-night respiration rates in the phyllosphere. Finally, we show that seagrass-driven alterations of the rhizosphere pH microenvironment leads to development of low-pH microniches around the below-ground tissue, corresponding to the seagrass-derived oxic microzones, that results in pronounced rhizospheric phosphorus and iron mobilization for seagrasses colonizing phosphorous-limited carbonate-rich sediments.

The results of this thesis brings to light the overarching importance of internal tissue aeration in seagrasses through its effect on rhizospheric biogeochemical processes and conditions, and thus underlines the need for minimizing environmental stressors leading to inadequate internal aeration, such as water-column hypoxia and sediment re-suspension, for seagrass health in changing oceans.