

An underwater photograph showing a white buoy with an orange rope attached, floating in the water. Below the buoy, a dense field of green seagrass is visible, with a blue and white object partially submerged in the foreground. The water is clear and greenish.

THE SEAGRASS RHIZOSPHERE

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The Seagrass Rhizosphere

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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.

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

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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.