Multilevel Assessment of Seagrass Response to Thermal Stress: Stress Memory and Epigenetic Changes

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Abstract

Seagrasses are being threatened globally due to human-induced environmental changes with ocean warming being one of the main players. A better understanding of the interaction between seagrasses and warming is, therefore, crucial to secure a sustainable future for these paramount foundation species.

Through a literature review and a series of *ad hoc* mesocosm and field experiments using four seagrass species from the northern (i.e. Mediterranean: *Posidonia oceanica*, *Cymodocea nodosa*) and southern (i.e. Australia: *Posidonia australis* and *Zostera muelleri*) hemisphere and by applying multi- and inter-disciplinary approaches [i.e. photo-physiology, growth, pigments, gene expression (RT-qPCR and RNA-seq), and genome screening (ddRADseq)], here I (***i***) identify potential commonalities in the effects of warming and the responses of seagrasses across different levels ranging from molecular to planetary [e.g. warming strongly affects seagrasses at all levels while seagrass responses diverge amongst species, populations and over depths]; (***ii***) demonstrate the existence of thermal stress memory for the first time in seagrasses [e.g. non-primed plants suffered significant reduction in photosynthetic capacity, leaf growth and pigments content, while heat-primed plants were able to cope better with recurrent stressful events]; (***iii***) reveal the molecular mechanisms that potentially govern the formation (priming phase) and activation (memory phase) of thermal stress memory in seagrasses [e.g. response to warming of non-primed plants required the involvement of several cellular compartments and processes while in heat-primed plants the response focused on a more limited group of processes]; (***iv***) explore the involvement of epigenetic modifications (DNA methylation and histone modifications in particular) in thermal stress response and thermal stress memory in seagrasses [e.g. results from gene expression analyses demonstrated a high activation of genes related to epigenetic modifications and thermal stress memory during the triggering event in both heat-primed and non-primed plants]; (***v***) broaden our knowledge in interspecific divergences in response to warming among seagrass species (northern versus southern hemisphere seagrasses and climax versus pioneer species) [e.g. results showed that northern hemisphere *Posidonia* better dealt with warming than its southern hemisphere counterpart and, in both hemispheres, pioneer seagrasses were more thermal tolerant than climax ones]; (***vi***) investigate the molecular basis of local adaptation to high temperature condition in seagrasses [e.g. ddRADseq data analysis identified several outlier loci potentially responsible for thermal stress response and epigenetics]; and finally (***vii***) suggest future directions for seagrass research [e.g. studies involving additional species and populations, investigation of the seagrass holobiont, seagrasses as a solution to mitigate climate change among others].

This thesis provides novel insights into the field of seagrass ecology and yields potential implications for future seagrass conservation and restoration activities in an era of ocean warming.

Keywords: Seagrass, *Posidonia oceanica*, *Cymodocea nodosa*, *Posidonia australis*, *Zostera muelleri*, Marine heatwave, Heat stress, Stress memory, Epigenetics.