Draft – Effect of Atmospheric Heatwaves on Reflectance and Pigment Composition of Intertidal *Nanozostera noltei* – Draft

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Abstract

To be written

Keywords: Remote Sensing, Pigment Composition, Seagrass, Coastal Ecosystems, Heatwaves

1. Introduction

Intertidal seagrasses play a crucial role in the ecosystem by providing habitats and feeding grounds for various marine species, supporting rich marine biodiversity, and contributing significantly to primary production and carbon sequestration [1, 2]. These seagrasses are essential in maintaining the health of coastal ecosystems by stabilizing sediments, filtering water, and serving as indicators of environmental changes due to their sensitivity to water quality variations [3]. The interactions between seagrass meadows and their associated herbivores further enhance the delivery of ecosystem services, including coastal protection and fisheries support [4, 5, 6]. Understanding and preserving these ecosystems are vital for maintaining the biodiversity and productivity of coastal regions [7, 8].

Despite their crucial role in marine ecosystems, intertidal seagrasses face numerous threats that compromise their health and functionality. Coastal development and human activities are primary threats. These activities not only reduce the available habitat for seagrasses but also increase water turbidity, which limits light penetration and hampers photosynthesis [9]. Seagrasses are also threatened by nutrient enrichment from agricultural and urban runoff, which can lead to eutrophication. This condition promotes the overgrowth of algal blooms that

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compete with seagrasses for light and nutrients, further stressing these important plants [10] (Oiry et al. 2024). Pollution from industrial and municipal sources introduces harmful chemicals and heavy metals into coastal waters, posing toxic risks to seagrass health. These pollutants can affect the physiological processes of seagrasses, reducing their growth and survival rates [11] Additionally, invasive species can out compete native seagrasses for resources, altering community structure and function [12].

Heatwaves, exacerbated by climate change, pose a growing threat to seagrasses. Marine Heatwaves (MHW), defined by [13] as prolonged discrete anomalously warm water events, and Atmospheric Heatwaves (AHW), defined by [14] as periods of at least three consecutive days with temperatures exceeding the 90th percentile, cause severe physiological stress on seagrasses [15, 16]. At the interface between the land and oceans, intertidal seagrasses are exposed to both MHW and AHW. Heatwaves have profound impacts on seagrasses, with their effects varying based on species and geographic location. For instance, the seagrass *Zostera marina* exhibits high susceptibility to elevated sea surface temperatures during winter and spring, leading to advanced flowering, high mortality rates, and reduced biomass [15]. Similarly, *Cymodocea nodosa* shows increased photosynthetic activity during heatwaves but suffers negative effects on photosynthetic performance and leaf biomass during recovery [16]. Additionally, different populations of *Zostera marina* along the European thermal gradient exhibit varied photophysiological responses during the recovery phase of heatwaves, indicating differential adaptation capabilities among populations [17]. These events intensify other stressors, such as overgrazing and seed burial, compromising sexual recruitment [18].

Remote sensing is increasingly being utilized to monitor marine ecosystems, including seagrass meadows. Through the Water Framework Directive and the Marine Strategy Framework Directive, Europe is promoting remote sensing techniques for habitat mapping, as these methods enable the monitoring of extensive areas over time [19]. By using spectral indices, such as the Normalized Difference Vegetation Index (NDVI) and the Soil-Adjusted Vegetation Index (SAVI), or by analyzing specific spectral patterns, remote sensing can effectively quantify vegetation health over time [20, 21, 22, 23]. Bleaching and browning events of seagrass beds have been observed following episodes of intense heat along the Brittany coast of France (Pers. obs.). This study will experimentally test the hypothesis that warm events modify the pigment composition and reflectance of seagrass, linking these changes with satellite remote sensing.

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