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

Simon Oiry

Bede Ffinian Rowe Davies

Philippe Rosa

Augustin Debly

Pierre Gernez

Laurent Barillé

2024-07-10

Abstract

To be written

# 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 (Sousa et al., 2019; Unsworth et al., 2022). 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 (Zoffoli et al., 2021). The interactions between seagrass meadows and their associated herbivores further enhance the delivery of ecosystem services, including coastal protection and fisheries support (Gardner and Finlayson, 2018; Jankowska et al., 2019; Zoffoli et al., 2023). Understanding and preserving these ecosystems are vital for maintaining the biodiversity and productivity of coastal regions (Ramesh and Mohanraju, 2020; Scott et al., 2018).

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 (Waycott et al., 2009). 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 compete with seagrasses for light and nutrients, further stressing these important plants (Thomsen et al., 2023) (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 (Sevgi and Leblebici, 2022) Additionally, invasive species can out compete native seagrasses for resources, altering community structure and function (Simpson et al., 2016).

Heatwaves, exacerbated by climate change, pose a growing threat to seagrasses. Marine Heatwaves (MHW), defined by Hobday et al. (2016) as prolonged discrete anomalously warm water events, and Atmospheric Heatwaves (AHW), defined by Perkins and Alexander (2013) as periods of at least three consecutive days with temperatures exceeding the 90th percentile, cause severe physiological stress on seagrasses (Deguette et al., 2022; Sawall et al., 2021). 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 (Sawall et al., 2021). Similarly, *Cymodocea nodosa* shows increased photosynthetic activity during heatwaves but suffers negative effects on photosynthetic performance and leaf biomass during recovery (Deguette et al., 2022). 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 (Winters et al., 2011). These events intensify other stressors, such as overgrazing and seed burial, compromising sexual recruitment (Guerrero-Meseguer et al., 2020).

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 (Papathanasopoulou et al., 2019). 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 (Akbar et al., 2020; Cârlan et al., 2020; Huete, 2012; Kloos et al., 2021). 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.

# 2. Bibliography

Akbar, M., Arisanto, P., Sukirno, B., Merdeka, P., Priadhi, M., Zallesa, S., 2020. Mangrove vegetation health index analysis by implementing NDVI (normalized difference vegetation index) classification method on sentinel-2 image data case study: Segara anakan, kabupaten cilacap, in: IOP Conference Series: Earth and Environmental Science. IOP Publishing, p. 012069.

Cârlan, I., Mihai, B.-A., Nistor, C., Große-Stoltenberg, A., 2020. Identifying urban vegetation stress factors based on open access remote sensing imagery and field observations. Ecological Informatics 55, 101032.

Deguette, A., Barrote, I., Silva, J., 2022. Physiological and morphological effects of a marine heatwave on the seagrass cymodocea nodosa. Scientific Reports 12, 7950.

Gardner, R.C., Finlayson, C., 2018. Global wetland outlook: State of the world’s wetlands and their services to people, in: Ramsar Convention Secretariat. pp. 2020–5.

Guerrero-Meseguer, L., Marı́n, A., Sanz-Lázaro, C., 2020. Heat wave intensity can vary the cumulative effects of multiple environmental stressors on posidonia oceanica seedlings. Marine Environmental Research 159, 105001.

Hobday, A.J., Alexander, L.V., Perkins, S.E., Smale, D.A., Straub, S.C., Oliver, E.C., Benthuysen, J.A., Burrows, M.T., Donat, M.G., Feng, M., others, 2016. A hierarchical approach to defining marine heatwaves. Progress in oceanography 141, 227–238.

Huete, A.R., 2012. Vegetation indices, remote sensing and forest monitoring. Geography Compass 6, 513–532.

Jankowska, E., Michel, L.N., Lepoint, G., Włodarska-Kowalczuk, M., 2019. Stabilizing effects of seagrass meadows on coastal water benthic food webs. Journal of Experimental Marine Biology and Ecology 510, 54–63.

Kloos, S., Yuan, Y., Castelli, M., Menzel, A., 2021. Agricultural drought detection with MODIS based vegetation health indices in southeast germany. Remote Sensing 13, 3907.

Papathanasopoulou, E., Simis, S., Alikas, K., Ansper, A., Anttila, J., Barillé, A., Barillé, L., Brando, V., Bresciani, M., Bučas, M., others, 2019. Satellite-assisted monitoring of water quality to support the implementation of the water framework directive. EOMORES white paper.

Perkins, S.E., Alexander, L.V., 2013. On the measurement of heat waves. Journal of climate 26, 4500–4517.

Ramesh, C., Mohanraju, R., 2020. Seagrass ecosystems of andaman and nicobar islands: Status and future perspective. Environmental & Earth Sciences Research Journal 7.

Sawall, Y., Ito, M., Pansch, C., 2021. Chronically elevated sea surface temperatures revealed high susceptibility of the eelgrass zostera marina to winter and spring warming. Limnology and Oceanography 66, 4112–4124.

Scott, A.L., York, P.H., Duncan, C., Macreadie, P.I., Connolly, R.M., Ellis, M.T., Jarvis, J.C., Jinks, K.I., Marsh, H., Rasheed, M.A., 2018. The role of herbivory in structuring tropical seagrass ecosystem service delivery. Frontiers in Plant Science 9, 127.

Sevgi, K., Leblebici, S., 2022. Bitkilerde ağır metal stresine verilen fizyolojik ve moleküler yanıtlar. Journal of Anatolian Environmental and Animal Sciences 7, 528–536.

Simpson, T.S., Wernberg, T., McDonald, J.I., 2016. Distribution and localised effects of the invasive ascidian didemnum perlucidum (monniot 1983) in an urban estuary. PLoS One 11, e0154201.

Sousa, A.I., Silva, J.F. da, Azevedo, A., Lillebø, A.I., 2019. Blue carbon stock in zostera noltei meadows at ria de aveiro coastal lagoon (portugal) over a decade. Scientific reports 9, 14387.

Thomsen, E., Herbeck, L.S., Viana, I.G., Jennerjahn, T.C., 2023. Meadow trophic status regulates the nitrogen filter function of tropical seagrasses in seasonally eutrophic coastal waters. Limnology and Oceanography 68, 1906–1919.

Unsworth, R.K., Cullen-Unsworth, L.C., Jones, B.L., Lilley, R.J., 2022. The planetary role of seagrass conservation. Science 377, 609–613.

Waycott, M., Duarte, C.M., Carruthers, T.J., Orth, R.J., Dennison, W.C., Olyarnik, S., Calladine, A., Fourqurean, J.W., Heck Jr, K.L., Hughes, A.R., others, 2009. Accelerating loss of seagrasses across the globe threatens coastal ecosystems. Proceedings of the national academy of sciences 106, 12377–12381.

Winters, G., Nelle, P., Fricke, B., Rauch, G., Reusch, T.B., 2011. Effects of a simulated heat wave on photophysiology and gene expression of high-and low-latitude populations of zostera marina. Marine Ecology Progress Series 435, 83–95.

Zoffoli, M.L., Gernez, P., Godet, L., Peters, S., Oiry, S., Barillé, L., 2021. Decadal increase in the ecological status of a north-atlantic intertidal seagrass meadow observed with multi-mission satellite time-series. Ecological Indicators 130, 108033.

Zoffoli, M.L., Gernez, P., Oiry, S., Godet, L., Dalloyau, S., Davies, B.F.R., Barillé, L., 2023. Remote sensing in seagrass ecology: Coupled dynamics between migratory herbivorous birds and intertidal meadows observed by satellite during four decades. Remote Sensing in Ecology and Conservation 9, 420–433.