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Physiological and molecular evidence of differential short-term heat tolerance in Mediterranean seagrasses

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The increase in extreme heat events associated to global warming threatens seagrass ecosystems, likely by affecting key plant physiological processes such as photosynthesis and respiration. Understanding species' ability to acclimate to warming is crucial to better predict their future trends. Here, we study tolerance to warming in two key Mediterranean seagrasses, *Posidonia oceanica* and *Cymodocea nodosa*. Stress responses of shallow and deep plants were followed during and after short-term heat exposure in mesocosms by coupling photo-physiological measures with analysis of expression of photosynthesis and stress-related genes. Contrasting tolerance and capacity to heat acclimation were shown by shallow and deep *P. oceanica* ecotypes. While shallow plants acclimated through respiratory homeostasis and activation of photo-protective mechanisms, deep ones experienced photosynthetic injury and impaired carbon balance. This suggests that *P. oceanica* ecotypes are thermally adapted to local conditions and that Mediterranean warming will likely diversely affect deep and shallow meadow stands. On the other hand, contrasting mechanisms of heat-acclimation were adopted by the two species. *P. oceanica* regulates photosynthesis and respiration at the level of control plants while *C. nodosa* balances both processes at enhanced rates. These acclimation discrepancies are discussed in relation to inherent attributes of the two species.

Ongoing human-induced climate change are among the main threats affecting persistence and functioning of natural ecosystems[1]. Climate is predicted to experience not only a pronounced warming in the coming decades, but also a substantial increase in its inter-annual temperature variability, giving rise to more frequent, more intense and longer lasting summer heat waves[2]. These extreme thermal events intensify and prolong normal thermal stratification of marine waters and have been identified as the cause of massive mortality of sessile benthic key species[3]. Understanding how coastal key benthic species, in particular habitat-foundation species, respond to extreme heat events is imperative to predict how coastal ecosystems will respond to climate change[4].

Sublittoral bottoms along the coasts of tropical, subtropical and temperate seas are dominated by seagrasses[5], which are ecosystem engineers that structure one of the most valuable ecosystems in the biosphere, the underwater seagrass meadows[6]. Seagrass meadows produce goods and provide ecological services that are beneficial to humans and are key for the functioning of the marine coastal environment[7]. These valuable coastal ecosystems are potentially affected by anomalous heat events with critical consequences on their ecological and socio-economic functions and services[8].

Increased mortalities have been reported for several seagrass species after recent summer heat waves[9–11]. Nevertheless, the experimental evidence of direct cause-effect relationship is not yet available, except for two *Zostera* species (see below), and little is known in general about the response of seagrasses to warming. It is assumed that seagrasses experience carbon imbalance under moderate heat stress due to a proportional higher increase in respiration than in photosynthesis, undergoing irreversible damage on their photosynthetic apparatus when the stress reaches critical levels[12]. Indeed, photosynthesis is the most heat sensitive key physiological

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