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CONSERVATION ECOLOGY – ORIGINAL RESEARCH

Seagrass collapse due to synergistic stressors is not anticipated by phenological changes

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Abstract
Seagrasses are globally declining and often their loss is due to synergies among stressors. We investigated the interactive effects of eutrophication and burial on the Mediterranean seagrass, *Posidonia oceanica*. A field experiment was conducted to estimate whether shoot survival depends on the interactive effects of three levels of intensity of both stressors and to identify early changes in plants (i.e., morphological, physiological and biochemical, and expression of stress-related genes) that may serve to detect signals of imminent shoot density collapse. Sediment burial and nutrient enrichment produced interactive effects on *P. oceanica* shoot survival, as high nutrient levels had the potential to accelerate the regression of the seagrass exposed to high burial (HB). After 11 weeks, HB in combination with either high or medium nutrient enrichment caused a shoot loss of about 60%. Changes in morphology were poor predictors of the seagrass decline. Likewise, few biochemical variables were associated with *P. oceanica* survival (the phenolics, ORAC and leaf $\delta^{34}S$). In contrast, the expression of target genes had the highest correlation with plant survival: photosynthetic genes (ATPa, psbD and psbA) were up-regulated in response to high burial, while carbon metabolism genes (CA-chl, PGK and GADPH) were down-regulated. Therefore, die-offs due to high sedimentation rate in eutrophic areas can only be anticipated by altered expression of stress-related genes that may warn the imminent seagrass collapse. Management of local stressors, such as nutrient pollution, may enhance seagrass resilience in the face of the intensification of extreme climate events, such as floods.

Keywords Burial · Early warnings · Eutrophication · Multiple stressors · *Posidonia oceanica*

Introduction

Transitions between natural systems with radically different properties can occur abruptly. Important examples can be found in ecology (e.g., lake eutrophication and coral reef collapses), where regime shifts have consequences that are often irreversible (Bellwood et al. 2004; Carpenter 2011; Perry and Morgan 2017). Predicting and

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